Spring 2020
Space-Counterspace Industry Study Group Report

The United States Space Force: From Science Fiction to Science Fact

The Dwight D. Eisenhower School for National Security and Resource Strategy

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SPACE-COUNTERSPACE (2020)

<u>EXECUTIVE SUMMARY</u>: Since 1957, the space domain has transitioned from a protected domain for peaceful exploration to the ultimate high ground for great power competition. While the U.S. is the world's most capable space-faring nation, it is also the most dependent on space, especially for national security purposes. Recent nefarious actions of great power competitors reveal that U.S. assets in space are increasingly vulnerable as the space domain becomes more contested. The U.S.'s freedom to operate in space is a key element of national power. As such, the United States Space Force (USSF) was created in December 2019, to guarantee domain superiority in the event warfighting extends to the space domain, and to secure United States (U.S.) interests in space in the face of rising great power competition.[1]

The paper begins by defining primary missions for the new USSF and legacy space organizations, focusing on the debate over how to prioritize the missions. This is followed by a gap analysis between mission and resource strategy, based on examination of available procurement and research budgets for the major U.S. military-related space organizations. An examination of industry status to meet the challenges associated with procuring mature and emerging technology required for military space missions. A discussion follows analyzing non-materiel approaches to supporting the USSF mission, deterrence and burden sharing amongst allies, and space governance challenges. Finally, stakeholder issues are considered, including political and policy debates shaping resourcing alternatives/

The USSF's top priority must be to achieve Domain Superiority. Subsequent priorities include support to the Joint fight, establish an architecture that is supportive of future Globally Integrated Operations, and continue critical support to the nuclear and intelligence missions. The USSF must communicate a clear, coherent, and prioritized mission strategy and strive for mission consolidation over time. The timing of the consolidation of sister-Service and Space Development Agency (SDA) capabilities is an area that requires an in-depth study to prevent the USSF from inadvertently accepting shortfalls in personnel or resources, or degrading the potential of technological innovation. The eventual consolidation of the USSF, intelligence community space, the SDA, and military space Service budgets and personnel will create long-term fiscal efficiency and transparency. Furthermore, comptroller and flattened acquisition authority should be under the authority of the USSF to avoid resistance to a traditionally complex approval process when procuring mature technology.

External to the Department of Defense, the USSF must work in close coordination with allies and partners to develop innovative methods to deal with and defend against emerging counterspace threats. Simultaneously, the USSF must work with inter-agency partners and commercial entities to ensure the growth of the space industry to maintain a strong National Security Space base.

The creation of the USSF put the nation on an upward trajectory for space dominance. Proactive measures to secure Domain Superiority will ensure freedom of operations in space and protect America's national security far into the future.

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INTRODUCTION

A 2019 study by Air Force Space Command asserted history has passed the tipping point where space has now become a "key element of national power." [2] In response, the United States Space Force (USSF) was created in December 2019, to guarantee domain superiority in the event warfighting extends to the space domain, and to secure United States (U.S.) interests in space in the face of rising great power competition.[3]

This report summarizes the findings of the 2020 Space-Counterspace Industry Study (SPC-IS) seminar, at the Dwight D. Eisenhower School (ES) for National Security and Resource Strategy, National Defense University (NDU). The paper analyzes both materiel and non-materiel solutions available for implementation by the Department of Defense (DoD) to create synergy as USSF establishes its mission and resourcing strategies.

The paper begins by defining primary missions for the new USSF and legacy space organizations, focusing on the debate over how to prioritize the missions. This is followed by a gap analysis between mission and resource strategy, based on examination of available procurement and research budgets for the major U.S. military-related space organizations. An examination of industry status to meet the challenges associated with procuring mature and emerging technology required for military space missions. A discussion follows analyzing non-materiel approaches to supporting the USSF mission, deterrence and burden sharing amongst allies, and space governance challenges. Finally, stakeholder issues are considered, including political and policy debates shaping resourcing alternatives. Several appendices examine special topics, including surge and mobilization issues related to the space industry.

STRATEGIC ENVIRONMENT SURROUNDING SPACE ACTIVITIES

As a starting point, it is useful to briefly review trends in the strategic environment to understand today's critical inflection point that drove the creation of the USSF. In 1957 at the heart of the Cold War, Sputnik became the first artificial object placed into orbit. The Soviet Union and the United States sought to advance missile and space technology to gain nuclear hegemony. Public perception shifted in the late 1960s, as the U.S. landed a human on the moon. This gave rise to a new chapter in space history, focused on peaceful scientific exploration, with National Aeronautics and Space Administration (NASA) and academic institutions taking center stage. As time progressed, space technology transformed civil, commercial, and conventional military activities, becoming integrated into daily life, and attracting more and more participants.

Through the U.S.'s evolution of space activities, it became the world's most capable space-faring nation, but it also became the most dependent on space, especially for national security purposes. U.S. military power became dependent on space capabilities for the unique advantages they provided. Beginning in the Gulf War, America demonstrated the effects of an asymmetric advantage in space during wartime operations. U.S. satellites of all types – communications, intelligence-surveillance-reconnaissance, precision-navigation-and-timing, and warning platforms – played a decisive role, as coalition forces defeated the world's fourth-largest army in two days. Russian and Chinese strategists concluded that in future conflicts, they must be able to degrade the U.S.'s space advantage. In 2007, when China publicly demonstrated an anti-satellite (ASAT) kinetic-kill weapon, the status quo in space shifted again. Conventional warfighting threats, not directly tied to nuclear conflict, now unquestionably extended to the space domain. To protect and defend U.S. assets in an increasingly contested space domain, national leaders acted in 2019 by creating a new service dedicated to training, organizing, and equipping for a space superiority mission – the USSF. However, determining the balance between supporting the joint fight, and developing the transformative technology and doctrine needed for space superiority is one of the biggest challenges facing the USSF

MISSION ANALYSIS: COMPETING SCHOOLS OF THOUGHT FOR MILITARY SPACE MISSIONS

In 2019, Aerospace Corporation published a paper by Russ Rumbaugh on "Competing Schools of Operational Thought in Space."[4] The NDU-ES 2020 SPC-IS seminar adapted the nomenclature of that paper to create five national security Space Mission Areas (SMAs) as a framework for analysis.[a] Table 1 shows the SMAs: *Domain Superiority-Space Force Mission* (DS-SF); *Space Support to the Title 10 Legacy Joint Fight* (SS-T10); *Space Support to Future Transformative Warfare* (SS-TW); *Space Support to the Nuclear Mission* (SS-NM); and, *Space Support to the Title 50 Mission* (SS-T50). Each SMA in the table defines a line-of-effort that connects Strategy (Ends, first column) to Resourcing (Ways and Means, remaining columns). The Ways and Means columns indicate how resourcing the materiel solutions for each SMA differs with respect to the type of systems procured, time horizons for fielding the capabilities, and who are the lead budget, requirements, and acquisition agencies. The final column outlines the maturity for production within the industrial base for the types of systems and technologies required, and whether traditional or new suppliers will likely play key roles. For some SMAs, systems should be in production within the Future Years Defense Program (FYDP). For other SMAs, the needed technologies may take much longer to mature. In most cases, research and development (R&D) funding must be invested now to ensure timely fielding of systems needed for a given SMA.

Per the analysis of the SPC-IS seminar, Table 1 organizes Space Mission Areas in priority order for DoD, with the highest priority at the top. What follows is a detailed discussion of each SMA, including arguments for the prioritization indicated, and a critique of the Ways and Means currently employed in pursuit of these objectives.

Domain Superiority Space Force Mission (DS-SF). The Domain Superiority school of thought for the USSF is analogous to the Air Superiority concept for the Air Force. This SMA is seen as the key reason for the creation of USSF as a separate military service. *Rumbaugh* refers to this as "Space Control First." [5] Most of the space systems needed for this mission represent new requirements, comprising offensive and defensive space control capabilities. These systems are mainly not-yet-fielded and not-yet-mature in the industrial base. Therefore, near-term funding for this SMA must focus on rapid R&D spending, followed by steady procurement budgets in the near-to-mid-term. Most items in this area are in the classified budget, with acquisition managed by the Space Rapid Capabilities Office (SpRCO). U.S. Space Command (USSPACECOM) has primary responsibility for these requirements with additional requirements from other supporting Combatant Commands. Funding for this SMA is part of the USSF budget, starting in Fiscal Year 2022 (FY22). Moving to the mid-term, Domain Superiority (DS-SF) will likely require re-configuring of the overall U.S. military space architecture to ensure continued

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[a] The NDU-ES Space Mission Areas (SMAs) shown in Table 1 are adapted from a 2019 report by Russ Rumbaugh, Aerospace Corporation, "What Place for Space: Competing Schools of Operational Thought in Space."

Table 1. Prioritizing Space Mission Areas (SMAs): Ends vs. Ways & Means

STRATEGY -- ENDS	RESOURCING -- WAYS and MEANS				
SPACE MISSION AREA	**PRIMARY SYSTEM PROCUREMENT FOCUS**	**CAPABILITY TIME HORIZON**	**BUDGET ORG // Mix of Budget $ Categories**	**ACQ LEAD ORG // RQMTS LEAD**	**INDUSTRY MATURITY // SUPPLIER FOCUS**
Domain Superiority-Space Force Mission (DS-SF)	New DS-SF Systems + Resilient Architecture	Near-Term (R&D), Mid-Term (Procurement), FYDP ++	USSF (classified) // R&D-$, then Procurement-$	Space Rapid Cap Office (SpRCO) //USSPACECOM	Lower TRL // Established + New
Space Support to Legacy Title-10 Joint Fight (SS-T10)	Next-Gen-SS-T10 Systems + Protection	Near-Term (Procurement), FYDP	USSF // Procurement-$, support by R&D	USSF-SMC // Geographic COCOMS	Mature // Established
Space Support to Transformative Warfare (SS-TW)	New Military-Specific pLEO Architecture	Near-Term (R&D) Long-Term (Procurement), 10+ Yrs	OSD // R&D-$	Space Dvlpmnt Agency (SDA) // OSD/R&E	Nascent // Established + New
Space Support to the Nuclear Mission (SS-NM)	Next-Gen SS-NM Systems	Near-Term, (Procurement), FYDP	USSF // Procurement-$, support by R&D	USSF-SMC // STRATCOM	Mature // Established
Space Support to Title-50 Mission (SS-T50)	Next-Gen SS-T50 Systems + Protection + New DS-SF	Near-Term (Procurement), Mid-Term (Procurement), FYDP ++	ODNI-USDI (classified) // Procurement-$ + R&D-$	NRO // ODNI-NGA-NSA	Mature (SS-T50), Lower TRL (DS-SF) // Established + New

freedom of operation in space in a highly contested environment. This level of architectural re-structuring necessitates the examination of the space architecture used to carry out legacy support to the Title-10 Joint Fight, discussed next. Architectural revision will necessitate additional research and development (R&D) funding for the mid-term to achieve the desired goals.

Space Support to the Legacy Title-10 Joint Fight (SS-T10). This SMA represents the continuation of legacy space support missions to terrestrial warfighters, previously provided by Air Force Space Command. *Rumbaugh* refers to this as "Keep the Plumbing Running."[6] This portfolio centers on protected military satellite communication systems, and the positioning, navigation, and timing (PNT) constellation, Global Positioning Satellite (GPS). As part of a natural evolution of technology, and to ensure no mission gaps, this SMA requires ongoing near- and mid-term procurement funds to replace and upgrade existing and next-generation space systems. Budget responsibility falls on the USSF starting FY22. The USSF will manage acquisitions through Space and Missile Systems Center (SMC) based on requirements set by the Combatant Commands. The defense industry has a mature capacity to manufacture these systems via established providers.

Space Support to Transformative Warfare (SS-TW). As the name suggests, this SMA centers on space support to long-term transformative warfare concepts being developed by the Space Development Agency (SDA). *Rumbaugh* refers to this as "Enable Global Missile War."

This school of thought "presumes that precision-guided missiles … are poised to fundamentally change how war is fought, so long as space-based capabilities for surveillance, targeting, and navigation are available." [7] Specifically, the SS-TW concept requires the proliferation and disaggregation of sensors into multiple orbital regimes to enable advances in both missile warning and missile attack. This futuristic war concept depends strongly on dedicated military satellite data transport layers, centered on a mega-constellation of small satellites in proliferated low Earth orbit (pLEO), with very low-latency data transfer rates. Such space systems, combined with artificial intelligence, information fusion, and machine-to-machine tipping and cueing, if successful, set the stage for implementing what is often called sensor-to-shooter (STS) operations, or globally integrated operations (GIO). Small satellites in pLEO are the fundamental space systems required in this SMA, along with military-grade sensors for this class of small satellites. Significant R&D funding is immediately needed because both the technology and industry maturity is low, and advancement will likely require ten years or longer. For now, the SDA resides within the Office of the Secretary of Defense (OSD) and is tasked with funding, acquisition, and requirements development for transformative warfare space technologies. However, the FY2020 National Defense Authorization Act (NDAA) specified the SDA would transfer to the control of the USSF in FY2022.

Space Support to the Nuclear Mission (SS-NM). This SMA focuses on the historic role of space support to the nuclear mission. *Rumbaugh* refers to this as the "Nukes Matter Most" school of thought. [8] Though this also represents legacy space support to the Title-10 Joint Fight, it is categorized as a distinct mission area just as U.S. Strategic Command (USSTRATCOM) is a distinct unified combatant command. The expectation is that this long-standing space support requirement will continue. The space systems of specific focus in the SS-NM mission area are overhead persistent infrared (OPIR), and nuclear-hardened command-and-control capabilities for U.S. nuclear response options. Current and next-generation SS-NM systems have unique requirements, such as extreme radiation-hardening, specialized security protocols, and extremely responsive protocols linked to a broader set of nuclear mission systems, such as ground-based radar, and missile defeat weapons. The budget for these systems will belong to the USSF, with its SMC unit handling acquisitions. USSTRATCOM, U.S. Northern Command (USNORTHCOM), and North American Aerospace Defense Command (NORAD) will champion SS-NM requirements. The near-term focus for procurements is on next-generation systems to replace legacy systems without creating mission gaps. For this SMA, an established set of producers exist in a mature defense industrial base. In the mid to long-term, strategists may disaggregate some capabilities currently fielded on the highly-integrated legacy SS-NM systems in support of the broader DS-SF mission. For example, for future OPIR, strategic missile warning could be disaggregated from theater missile warning. These trades will continue to evolve as the architectural plans continue to evolve for the Space Support to Transformational Warfare SMA.

Space Support for the Title-50 Mission (SS-T50). The 2020 NDU-ES SPC-IS seminar was not able to examine specific issues related to Title-50 space, due to limits imposed by Coronavirus Disease 2019 (COVID-19) visit restrictions. In addition, the FY20 NDAA did not fundamentally reshape the organizational relationship between Title-10 space, as now instantiated in the USSF, and Title-50 space, as historically led by the National Reconnaissance Office (NRO). Therefore, the SS-T50 SMA is presented in Table 1 in the last position, not because the seminar believes it is the lowest priority, but because it does not neatly fit into the analytic framework presented. Office of the Director of National Intelligence (ODNI), National

Geospatial-Intelligence Agency (NGA), and National Security Agency (NSA) set requirements for SS-T50. Budget authority rests with ODNI and the Undersecretary of Defense for Intelligence (USDI), while NRO handles procurement. However, NRO budget numbers cannot be discussed in an unclassified report. Suffice it to say; the SS-T50 SMA requires near- and mid-term funding to continue to provide legacy and next-generation systems, without mission gaps. A mature satellite industry exists to supply current and next-generation intelligence-gathering spacecraft. It is important to note that for the mid-to-long-term, the NRO is also investing R&D funding to investigate and pursue future architectures for increased resilience and space support to transformative missions.

A more detailed discussion of prioritization among the SMAs is required as a basis for resourcing decisions. While all SMAs share common aspects and are essential, the USSF must prioritize objectives. The SPC-IS seminar posits that the fledgling USSF should make its number one priority Space Domain Superiority. The fundamental driver for the creation of USSF is the rising threat to freedom of operation in space. As such, the fledgling USSF should make its number one priority, Space Domain Superiority. The success of all other mission areas hinges upon the USSF's ability to secure Space Domain Superiority. This viewpoint is a radical change to how the United States organizes, trains, and equips its space forces. In a 2020 joint exercise attended by the Joint Chiefs, for the first time, the Combatant Commanders supported USSPACECOM during a simulated attack on military space assets.[9] This event signals the high degree to which the warfighter has elevated space in the joint fight. The most urgent priority for the USSF is to generate new capability to protect and defend U.S. assets to ensure Space Domain Superiority.

As great power competition has once again become a central focus of U.S. grand strategy, the nation must continue to appropriately resource legacy space support missions to the Title-10 Joint Fight, which gives the U.S. military advantage over near-peer adversaries. Thus, the SS-T10 SMA is listed second in the priority list, because it has become integral and essential to the American way of war. Continuing to sustain and modernize satellite systems for PNT, weather, and satellite communication is vital to globally integrated operations.

The U.S. must not be overly focused on present mission needs. Complicated resource trades are necessary to shift from today's legacy systems to the space architectures needed for the transformative warfare vision of the future. That means the SS-TW SMA must be a high priority focus area for the USSF. Any delays in R&D related to demonstrating these pathfinding concepts will seriously erode the USSF ability to fight when called upon in the future.

The two remaining mission priorities are SS-NM and SS-T50. Space strategic missile warning capability is a national priority integral to defending the homeland against a nuclear strike. America must continue to fund nuclear and missile warning activities. However, there is some leeway in the potential trade-offs needed to meet mission objectives. It may be possible to use a simplified architecture with mature technologies for the SS-NM mission, rather than the exquisite legacy solutions. A simplified architecture could free resources for other SMAs. Similarly, military space support to national intelligence is essential to national security, and the nation must always fund this mission area. However, many agencies complement this mission area, and there may be an opportunity for burden-sharing to achieve the optimum overall national security space architecture.

The prioritized space mission area framework presented in Table 1 provides a synthesized basis for discussing resourcing decisions facing the USSF. Before proceeding to a budget gap analysis, it is useful to summarize the SMA prioritization analysis. Foremost is the objective to achieve Space Domain Superiority: to protect and defend U.S. interests in space, and negate adversary systems that place joint and coalition space systems at risk. Second is the need for the USSF support to the broader Joint Fight by securing and modernizing assets that are integral to the SS-10 SMA. Next, it is imperative to transform the USSF towards an architecture supportive of future GIO concepts, via proliferated sensors in multiple orbits, and military-specific data transport layers. The transformative architecture is needed to create an internet-of-things in space to achieve a truly connected global force with the ability to connect sensor-to-shooter in denied environments. Last, but certainly not least, is to continue critical support for nuclear and Title-50 intelligence activities, which are primarily resourced outside of the USSF.

To appropriately resource USSF priorities, the Service should adopt and communicate a clear, coherent, and prioritized mission strategy. This is key to arguing for limited budgets within the Pentagon and in the broader interagency budget battles. It is also crucial because the achievement of this prioritized strategy is heavily dependent on technology innovation, in both government R&D institutions and the defense industry. Therefore, clear, prioritized goals help fuel appropriately targeted investments in the national innovation base and help align a whole-of-government approach towards developing innovative technology. In the next sections, the articulation of a prioritized mission strategy also permits analysis of near-term budgetary and industry gaps the USSF must identify and resolve to answer the nation's call for space superiority.

MATERIEL GAP ANALYSIS: BUDGET

For the first time, the Fiscal Year 2021 (FY21) President's Budget (PB) request includes a budget for the newly created USSF. Historically, analyzing resource allocation for space requirements has been challenging without direct inside information, a high-level security clearance, and a need to know. Because space budgets were spread across a variety of elements within the military Services, the Intelligence Community (IC), and the Secretary of Defense's SDA, these budgets lacked transparency and efficiency. Congress began addressing this issue in the 2016 National Defense Authorization Act (NDAA) by making National Security Space requirements a Major Force Program (MFP), specifically MFP-12, thus requiring aggregation and better oversight.[10] The FY20 MFP-12 budget of $14 billion serves as the baseline, but even more could be accomplished going forward to facilitate oversight and coordination of the total national security space budget. With the creation of USSF, consolidating the budgets for IC space, the SDA, and military space Service personnel requirements, which are not currently part of MFP-12, would create greater efficiency and transparency for USSF missions.

As part of the FY21 PB, the DoD FY21 MFP-12 budget includes $18 billion of funding for the space warfighting domain. This includes the inaugural USSF budget of $15.4 billion, as shown in Figure 1.[11,12] The proportions represented in Figure 1 are noteworthy when contrasted with typical budgets for other military Services. In the broader DoD budget, 64 percent of funding is for Military Personnel and Operations and Maintenance (O&M), with only 35 percent for Investment (the combination of Procurement (PROC) funding, plus Research, Development, Test, and Evaluation (RDT&E) funding). In the USSF budget, this is reversed, with Investment comprising 83 percent of the budget. There are several reasons for this difference. First, legacy exquisite satellites, and the launches required to put satellites in orbit, are expensive, accounting for the majority of the $2.4 billion in PROC funding. However, the most remarkable feature of the USSF budget is that two-thirds is comprised of RDT&E funding. This says something fundamental about this military service. To an extraordinary degree, the success of the USSF depends on rapid and continuous technological innovation, both to establish the DS-SF mission area, and to maintain the nation's SS-T10 competitive advantage.[13] Furthermore, even though it is not yet a part of the USSF budget, SDA's budget is 100 percent RDT&E funding to support the long-term SS-TW mission. Although it is a relatively small $288 million in FY21, it quickly grows to over $2 billion in FY24.[14]

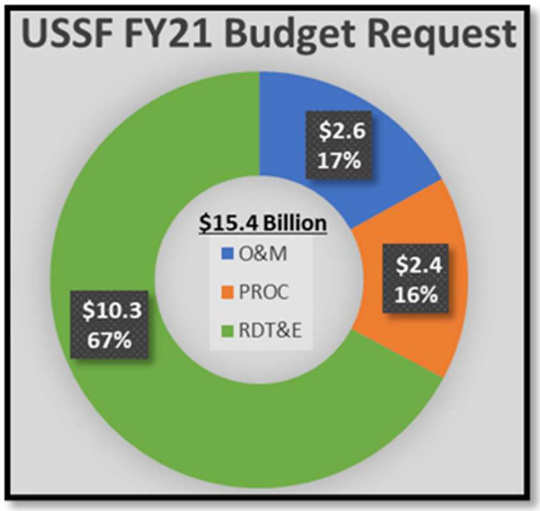

Figure 1: The USSF budget request for Fiscal Year 2021[15]

Budget uncertainty is nearly omnipresent in the DoD. The last year that regular appropriation bills were enacted before the start of the new fiscal years was in 1997. Since then, an average of five Continuing Resolutions (CRs) have been enacted before the start of the FY, and CR funding averaged five months of each FY.[16] Uncertainty is compounded in 2020 as the government spends trillions of dollars to mitigate the impacts of the COVID-19 global pandemic, combined with the upcoming Presidential election, exacerbate the ambiguity. Consequently, it is improbable that the DoD budget will grow from the PB21 baseline in the foreseeable future. Thus, the USSF must maximize the current level of funding by prioritizing requirements based on a strategic road-map to invest resources in the highest priority missions, protecting its DS-SF and SS-T10 crown jewels, while accepting some risk in lower priority missions.

The top six lines of Table 2 below depict the major space cost drivers across the PB21 FYDP. This illustrates the significant funding allocated across the space crown jewels, including classified programs, and the planned growth of that funding over the next several FYs. Fiscal success for the USSF will require continued funding, a thorough justification of prioritized requirements to realize the planned growth in the out years of the FYDP. Excluding classified programs and launch funding, the USSF FYDP is heavily skewed towards legacy and previously planned programs, with less than eight percent of funding supporting the DS-SF mission. Classified programs improve on that percentage, but there is a funding gap to support space as a warfighting domain. Said another way, DS-SF is the highest priority end, yet it is allocated the least means. As strategic priorities continue to evolve, new DS-SF requirements will emerge

Table 2: Major Space Cost Drivers across the PB21 FYDP[b,17,18,19]

SMA "Closest Fit"	Source of Funds	Space Program ($ millions)	FY21	FY22	FY23	FY24	FY25	FYDP Total
DS-SF ? SS-TW ? SS-T10 ?	USSF	Classified Programs	$ 3,711	$ 4,006	$ 4,351	$ 4,445	$ 4,736	$21,249
SS-NM	USSF	Overhead Persistent Infrared (OPIR)	$ 2,480	$ 2,328	$ 2,677	$ 3,083	$ 2,647	$13,215
SS-T10	USSF	Global Positioning System (GPS)	$ 1,813	$ 1,682	$ 1,535	$ 1,558	$ 994	$ 7,582
SS-T10	USSF	Satellite Communications (SATCOM)	$ 1,112	$ 1,034	$ 1,302	$ 1,994	$ 1,676	$ 7,118
SS-TW	SDA	National Defense Space Architecture (NDSA)	$ 288	$ 870	$ 1,288	$ 2,143	$ 1,983	$ 6,571
DS-SF	USSF	Space Control & Space Domain Awareness	$ 716	$ 961	$ 772	$ 763	$ 841	$ 4,052
ALL	USSF	National Security Space Launch (NSSL)	$ 1,604	$ 1,682	$ 1,659	$ 1,775	$ 1,952	$ 8,672
ALL	USSF	Other USSF Funding (O&M / other investment)	$ 3,946	$ 4,455	$ 4,696	$ 5,002	$ 4,852	$22,951
	USSF / SDA	Subtotal:	$15,671	$17,017	$18,280	$20,763	$19,680	$91,410
	Various	Delta (Army, Navy, other ?)	$ 2,329	?	?	?	?	?
		Major Force Program 12 Total:	$18,000	?	?	?	?	?

necessitating reallocation of funding from lower priority requirements. Fortunately, for the USSF, the PB21 funding levels for legacy and follow-on programs provide internal trade space to facilitate evolving programs. However, reallocation requires explicit strategic justification to protect funding from other DoD requirements, as it is well known inside the Pentagon that funding in play, is funding at risk.

Despite expected pressure on the DoD budget, the topline USSF budget will increase in the future, as space missions from the Army, Navy, and SDA transfer to the USSF to accomplish the DoD's goal of "unifying disparate space-related research, development, acquisition, fielding, and operations into a single organization." [20] The transfer of missions will include associated personnel and resources, which provides the USSF an opportunity to gain efficiencies via consolidated operations under a single military Service. Ideally, this results in savings to invest in priority DS-SF, SS-T10, and SS-TW requirements, further reducing operational risk. However, realizing savings will be dependent on effectively navigating inter-service rivalry as budget uncertainty may result in losing organizations underestimating the associated personnel and resources required to execute transferred missions. The timing of mission consolidation is critical to preserving capability. For now, allowing SDA to remain under OSD preserves the culture of experimentation and innovation. The USSF must grow their culture as one that accepts the risk that comes with exploring new technologies. The transition of the SDA into the USSF must occur in a manner that both organizations will continue to be successful. In essence, the USSF must conduct significant prior analysis to understand accompanying personnel and funding to ensure acceptable levels transfer with new missions, whether it is from OSD, Army, Navy, or other sister organizations. Failure to identify necessary resources before transfer will result in a reduction in buying power within the current baseline budget, thus decreasing overall effectiveness and increasing risk.

Although quantifying risk from under-resourced mission transfers is difficult, the "Delta" row at the bottom of Table 2 (see the red box) depicts the estimated non-USSF and SDA space

[b] Figures are estimates only, based on open-source PB21 documents cited in the endnotes.

funding in PB21 at $2 .3billion. This delta represents the budget needed from the other Services as these capabilities transition to the USSF. There is risk to the USSF budget as other Services try to protect their internal resources during the consolidation of capabilities. Given the budget, as mentioned above, the intricacies and importance of future funding to accomplish the mission, organic comptroller capability must be established within the USSF. Solely relying on comptroller support from the Air Force is another gap that should be addressed moving forward.

MATERIEL GAP ANALYSIS: INDUSTRIAL BASE & BUSINESS FACTORS

The previous section examined the alignment of mission strategy and resourcing strategy in terms of organizational authorities, acquisition plans, and military budget allocations. In this section, the analysis shifts to a focus on the capacity of the space industrial base to supply the space systems required for the emerging mission strategy. If gaps exist in the ability of the space industrial base to fulfill the five SMAs, alignments of Ways and Means with Ends must be specifically addressed as part of the resourcing strategy. The section starts with an overview of the broad space industrial base, then proceeds to a specific gap and alignment analysis.

Overview of the Space Industrial Base. The 2020 SPC-IS seminar spent several months comprehensively analyzing the space industrial base to establish a fundamental understanding of space markets, value chains, and business strategies. The space industry is a specialized sector within the aerospace and defense industry defined by manufacturing and service activities. The space manufacturing sector includes firms that develop, produce, and sustain rocket launch vehicles, satellites, and space-related ground equipment. The space services sector encompasses firms that use spacecraft to provide five primary services: (1) satellite telecommunications (SATCOM) services (network backhaul and direct-to-consumer); (2) space-based earth observation data products; (3) space-based science; (4) spacecraft ground operations services; and (5) space control.

Figure 2 provides a high-level summary of revenues by market segment from the Satellite Industry Association (SIA) 2019 State of the Satellite Industry report.[21] The global space industry achieved revenues of $360 billion in 2018, with a modest annual growth of 3 percent. The U.S. Department of Commerce (DoC) forecasts an industry expansion of $1 to3 trillion over the next 20 years.[22,23] The upstream segments of satellite manufacturing and launch services account for a small percentage of the revenues in the global space industry. The downstream elements of satellite services comprise the majority of revenues. Of note, satellite services revenue is an order of magnitude greater than satellite manufacturing revenue, and satellite manufacturing revenue is an order of magnitude greater than launch industry revenue. Overall, the industry remains healthy, with profit growth in all segments.

“Non-Satellite” revenues (grey segment in Figure 2) equate to the combined value of government space budgets globally, indicating government expenditures play a significant role in the space industry. Through this lens, differences in market dynamics can be examined according to product type: government or commercial. According to ideal economic theory, neither sector operates efficiently in the space industry. The government sector operates as a monopsony, with only one buyer. The commercial sector has historically operated as an oligopoly, with limited suppliers due to significant barriers to market entry. There are also dual-use elements in the space industry.

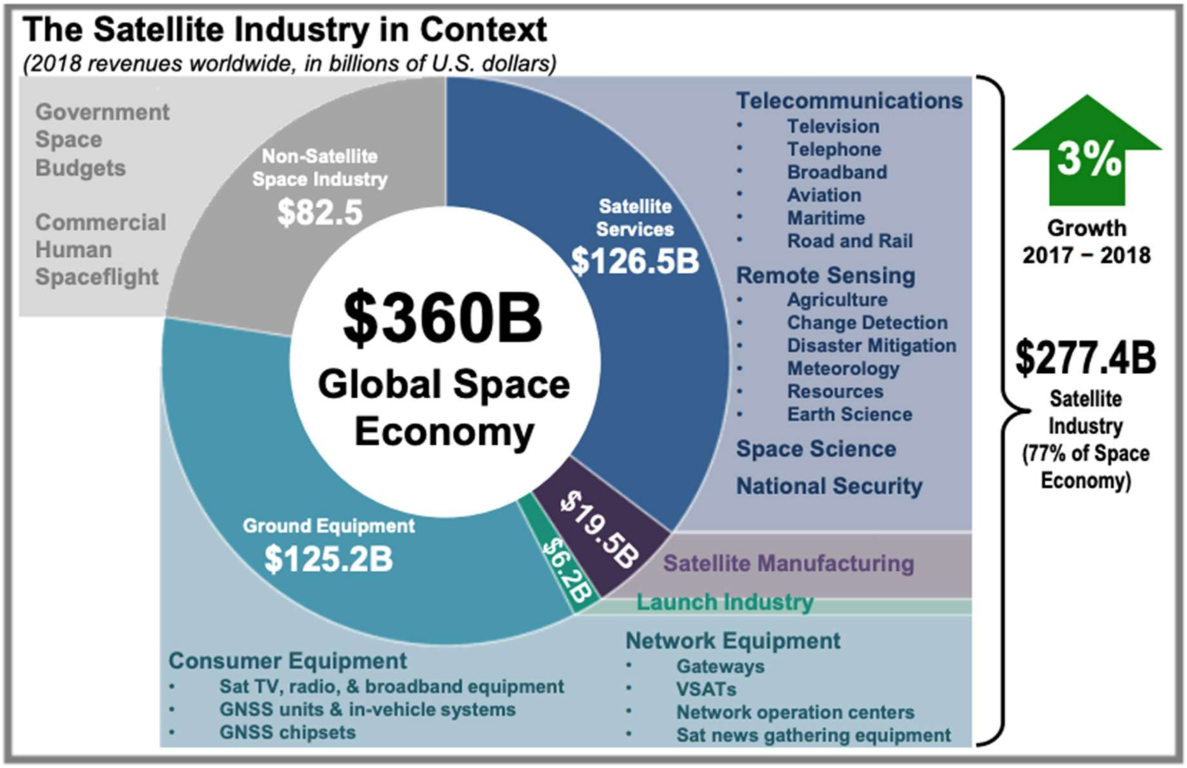

Figure 2: The Global Satellite Industry in Context by Market and Revenue in 2018[24]

Launch Overview. The space launch manufacturing and services sector provides unique products and services for governmental and commercial customers. Products in the value chain include liquid rocket engines, solid rockets motors, electric propulsion units, spacecraft thrusters, and specialized avionics. Launch services are nearly always provided by launch vehicle prime integrators.[25] Launch customers include the DoD, NASA, and commercial space service providers such as Intelsat, Iridium, and Maxar Technologies.[26] Major U.S. participants in the launch market include United Launch Alliance, SpaceX, Blue Origin LLC, Northrop Grumman, Boeing, Aerojet Rocketdyne, Electron Technologies, Firefly, General Dynamics OTS, Moog Inc., Nammo Talley (U.S. subsidiary, Norway), and Rocket Lab.[27]

Space launch is vital to U.S. national security and is an essential aspect of great power competition and the global economy. In 2018, launch accounted for only $6.2 billion in revenue, out of the $360 billion global space economy (1.7 percent). Although space launch is proportionally small compared to the overall industry, and traditionally on the low end of profitability, it has a critical and unique function in the upstream portion of the value chain. There are few competitors, and billions in capital investments are required to participate in the market. New entrants to the market, such as SpaceX and Rocket Lab, derive cost efficiencies through vertical integration (value chain consolidation) within a single company.

Satellite Manufacturing Overview. The satellite manufacturing market reached $19.5 billion in revenues in 2018 and comprised seven percent of the space economy.[28] The SIA assessed that $11.5 billion of this market was domestic (U.S.), with the government comprising 77 percent of the domestic market. Globally, there are relatively few major satellite manufacturers: Airbus, Boeing, Lockheed Martin, Northrop Grumman, and Mitsubishi Heavy Industries. Mid-sized companies include Ball Aerospace, Maxar Technologies (Maxar), and

Surry Satellite Technology. Due to the high level of specialization and knowledge required to meet stringent buyer performance requirements, satellite manufactures often become specialized in one, or a few, market sub-segments, such as communications, remote sensing, or science missions. Although the manufacture of satellites is expensive, complex, and time-consuming, it is a far less profitable market when compared to satellite services.

Satellite Services Overview. The satellite services sector by far generates the largest revenues of any market segment in the space industry, accounting for $126.5 billion in worldwide revenue in 2018 (excluding ground equipment). Within this segment, television and radio broadcast communications account for 80 percent of revenue, with broadband, cellular backhaul, and mobile satellite communication accounting for the remainder.[29] In 2019, the U.S. satellite telecommunications (SATCOM) market had annual revenue of $8.2 billion, with 2 to 3 percent growth projected from 2014 to 2024.[30] The SATCOM market has a two-tiered industry structure, with 75 percent of the market revenues dominated by a few satellite owner-operators (i.e., EchoStar, Intelsat SA, and SES SA). The other tier captures 25 percent of market share through purchasing telecommunication capabilities from the owner-operators and re-selling it downstream.[31]

Surge and Mobilization Overview. Surge and mobilization are not concepts that are traditionally associated with the space industry. Historically, space manufacturing is associated with long lead times, to facilitate the production of complex, no-fail products, catered to exquisite government requirements. It can take over four years to manufacture a national security space satellite. Components must undergo extensive testing after manufacture, and multiple components feed into the production of sub-assemblies.[32] The sub-assemblies are then individually tested, and multiple sub-assemblies are put together to form an assembly, which is also thoroughly tested. Assemblies form sub-systems and sub-systems form systems, with layers and layers of further testing at each stage. The availability of the smallest components, such as radiation-hardened electronic floating-point gate arrays, can become a pacing function in the manufacture of sophisticated satellites. However, customers, including DoD, may not have years to wait when a surge in production is required.

Beyond surge, mobilization requires a rapid expansion in not just the units produced, but in the very production infrastructure itself. This is also a challenge for the space industry, due to the complexity and high capital costs involved in building new space manufacturing factories. In lieu of that, it is interesting to note that in 2018 roughly 75 percent of domestic satellite manufacturing revenues came from U.S. government orders. At the same time, roughly 60 percent of the satellites launched (by number) were commercial satellites.[33] Thus, it appears that commercial demand drives satellite production capacity, but government orders drive satellite manufacturing revenues. This is because the highly specialized government satellite market is actually a different sub-market versus commercial satellite manufacturing. The question the U.S. government must answer is: how might it be possible to take advantage of commercial satellite production capacity in times of a national mobilization emergency?

Another critical need in any industry, when considering surge requirements, is how to surge the workforce to meet urgent demands. This is especially true in the space industry, which relies upon a workforce with highly specialized skills in engineering, science, manufacturing, information technology, and cybersecurity. The DoC and Government Accountability Office studies document a national shortage of Science, Technology, Engineering, and Mathematics (STEM) professionals in the space industry.[34,35,36] The shortage of STEM professionals results in cut-throat competition amongst space companies for this scarce resource. Compounding this shortage is the time required to obtain personnel security clearances to enable work on critical elements of the U.S. national security infrastructure. Public and private sector data identify the quickening retirement pace of space industry workers as another critical industrial base concern.[37,38]

Industry Alignment with Prioritized SMA Framework. The question remains about space industrial base gaps preventing the fulfillment of the five SMAs. The final column of Table 1 calls out "Industry Maturity" as a factor for each SMAs. Further detail on those determinations is presented here.

Table 3 presents a rough, qualitative analysis of how the industry maturity in each of the three major space markets (launch, satellite manufacturing, satellite services) aligns with mature (SS-T10, SS-NM, SS-T50) and emerging (DF-SD, SS-TW) SMAs. The first row indicates that the three SMAs are generally aligned with mature industry bases. These include *Space Support to the Title 10 Legacy Joint Fight* (SS-T10), *Space Support to the Nuclear Mission* (SS-NM), and *Space Support to the Title 50 Mission* (SS-T50). The remaining two SMAs rely more on emerging technology, namely *Domain Superiority-Space Force Mission* (DS-SF) and *Space Support to Future Transformative Warfare* (SS-TW).

In Table 3, the qualitative indicator green signifies that the industry is currently capable of meeting the established technical mission requirement set. Yellow indicates that there are likely limitations to the industry meeting that mission. Red denotes that the industry has not yet been fully established. One block in the chart (satellite manufacturing for the emerging industry) is shaded from red to green because it runs the gamut from being fully capable of building small satellites for specific missions, to concerns about the viability of the pLEO constellations portion of that market, to the nascent nature of the technology needed for the emerging mission area. The following discussion will delve further into these conclusions and discuss what the USSF and the DoD can do to support the industry to provide the technology needed for current and future fights.

Table 3: Industry Maturity Versus Industry Capability Stop-Light Chart

	Industry Capability		
Industry Maturity	**Launch**	**Satellite Manufacturing**	**Satellite Services**
Mature (SS-T10, SS-NM, SS-T50)			
Emerging (DS-SF, SS-TW)			

Note: Green signifies the industry sector is analyzed as currently capable of meeting mission requirements. Yellow indicates there are likely limitations to industry meeting that mission. Red denotes that the industry has not yet been fully established.

Mature Industry Capability Analysis by Market Sector

This section describes the 2020 SPC-IS seminar's analysis of the health and maturity of the established space industrial base and its ability to enable SMA implementation.

Launch tied to mature missions – Some limitations of meeting USSF needs. The health of the space launch industry relies heavily on government investment. In 2019, government customers accounted for 71 percent of global launch market revenues. The U.S. government customer represented 23 percent of global revenues, while U.S. launch service companies captured 37 percent of the global launch revenues. Notably, Russia had no commercial rocket launch revenue in 2019, while China had the highest number of launches.[39]

In the last 25 years, there has been significant market consolidation in the launch sector. For instance, solid rocket motor manufacturers decreased from six firms to two.[40] U.S. Government regulatory policy in the market tries to keep multiple manufacturers in place to foster innovation and competition. The USAF commissioned a report in 2020 to (1) evaluate if U.S. launch service providers could continue to support the heavy-lift launch market, and (2) understand how market forces are driving strategic business decisions within the heavy-lift industrial base.[41] The USAF, and ultimately the USSF, is responsible for procuring heavy-lift launch vehicles that are certified to launch National Security Space satellites. A heavy-lift launch vehicle can place a USSF satellite weighing over 14,000 kilograms into a geosynchronous transfer orbit. However, the average mass of commercial satellites is rapidly decreasing, leading to RAND's conclusion that the heavy-lift market is likely to see only moderate growth over the next decade and is unlikely to support more than one supplier. Nevertheless, U.S. policy requires the USSF to maintain a heavy-lift space launch industrial base with two or more suppliers.[42]

Satellite manufacturing tied to mature missions – Capable of meeting USSF needs. Satellite manufacturers must make significant investments in specialized fabrication equipment, such as large vacuum chambers, vibration, and acoustic testing apparatus, and exotic composites manufacturing. Critical, space-hardened electronic components often have long manufacturing lead times. Furthermore, electronic component orders for commercial satellites may be subject to delivery delays due to the Defense Production Act (DPA) Title I prioritization for electronic components supporting U.S. defense contracts. Because a significant portion of the satellite manufacturing industry is primarily driven by government priorities, manufacturers tend to focus on specific market niches, where their accumulated engineering expertise can be utilized to develop highly specialized products for demanding government customers. This specialization limits competition, as each provider has significant difficultly acquiring the necessary breadth of specialists to compete outside of its niche. The USSF should support this industry as the emerging capabilities mature. There will be a continuing need for these exquisite satellites and losing that U.S. capability could be detrimental to the security of the United States.

Satellite services tied to mature missions – Capable of meeting USSF needs. The commercial SATCOM sector is expected to expand over the next decade, especially with the current upgrades to high-throughput satellites.[43] Therefore, the USSF developed a vision for satellite communications that consolidate the responsibility for acquiring and managing SATCOM systems for the USSF and USSPACECOM. The desired end state is to provide joint warfighter support across the full spectrum of conflict and add more agility to the DoD's current processes, which is needed to support the SS-T10.[44]

Acquisition factors tied to mature missions – Authority and responsiveness are critical elements. The USSF SATCOM strategy states that the DoD must adopt acquisition strategies that take advantage of the growing space commercial market. These strategies should not be limited to SATCOM but should be applied to the entire space industry. The USSF Acquisition Corps must possess a flattened Milestone Decision Authority command chain rather than a hierarchical Joint Capabilities Integration and Development System (JCIDS) process to avoid resistance to a traditionally complex approval process when procuring mature technology. The USSF Acquisition Corps remains the best qualified to understand and accept the risk associated with space-based system development and procurement.

Emerging Industry Capability Analysis by Market Sector

This section describes the 2020 SPC-IS seminar's analysis of the health and maturity of the emerging space industrial base and its ability to enable SMA implementation.

Launch tied to emerging missions – Capable of meeting USSF needs. Since 2017, there have been significant changes in the industry dynamics due to new commercial entrants breaking through existing market barriers. There are contradicting views on the outlook of the industry. On the one hand, an emerging U.S small-rocket launch industry is making significant R&D investments, and some analysts predict significant market growth by 2024.[45] On the other hand, at the 2019 Satellite Conference, top executives from six large companies largely agreed that the market is crowded with too many launch service providers and not enough customers to service. These executives expect that some launch firms will exit the market in the next few years.[46] Regardless of market ups and downs, the U.S. Government must continue to regulate the space launch manufacturing industry and continually assess market investments in order to maintain this critical portion of the U.S. national security infrastructure.

Satellite manufacturing tied to emerging missions – Range: Capable, to not fully established in meeting USSF needs. Satellite manufacturing for emerging technologies runs the gamut from mature to non-existent, providing opportunities and challenges for this market sector. Commercial space companies such as Planet, Starlink, and OneWeb are developing pLEO constellations. These companies employ an assembly-line process and can complete the manufacture of a small satellite in a single shift. These small satellites are designed to last only two to three years in the harsh space environment. Conversely, large, complex satellites operating for over 15 years in space must withstand the constant radiation bath emanating from the sun. Planet, Starlink, and OneWeb accept that a small percentage of satellites may fail early in their projected life. Since the companies keep more satellites in orbit than required to meet minimum mission requirements, there is an on-orbit spare that is ready to take on the work of a failed satellite. When satellites reach their three-year end-of-life, they are replaced by satellites built using the latest technologies and innovations. The SDA is looking to mimic this highly resilient space architecture with its proliferated LEO constellation.

Both DARPA and the SDA recently released requests for proposal, describing a future vision for a space architecture featuring pLEO constellations. The proposed architectures incorporate a variety of layers for tracking, battle management, custody, navigation, deterrence, and support, as shown in SDA's version in Figure 3.[47] SDA anticipates that the industry will incorporate new technology every two years – mimicking Planet and Starlink in this regard. The agency's PB21 request is consistent with these goals. However, these types of proliferated LEO

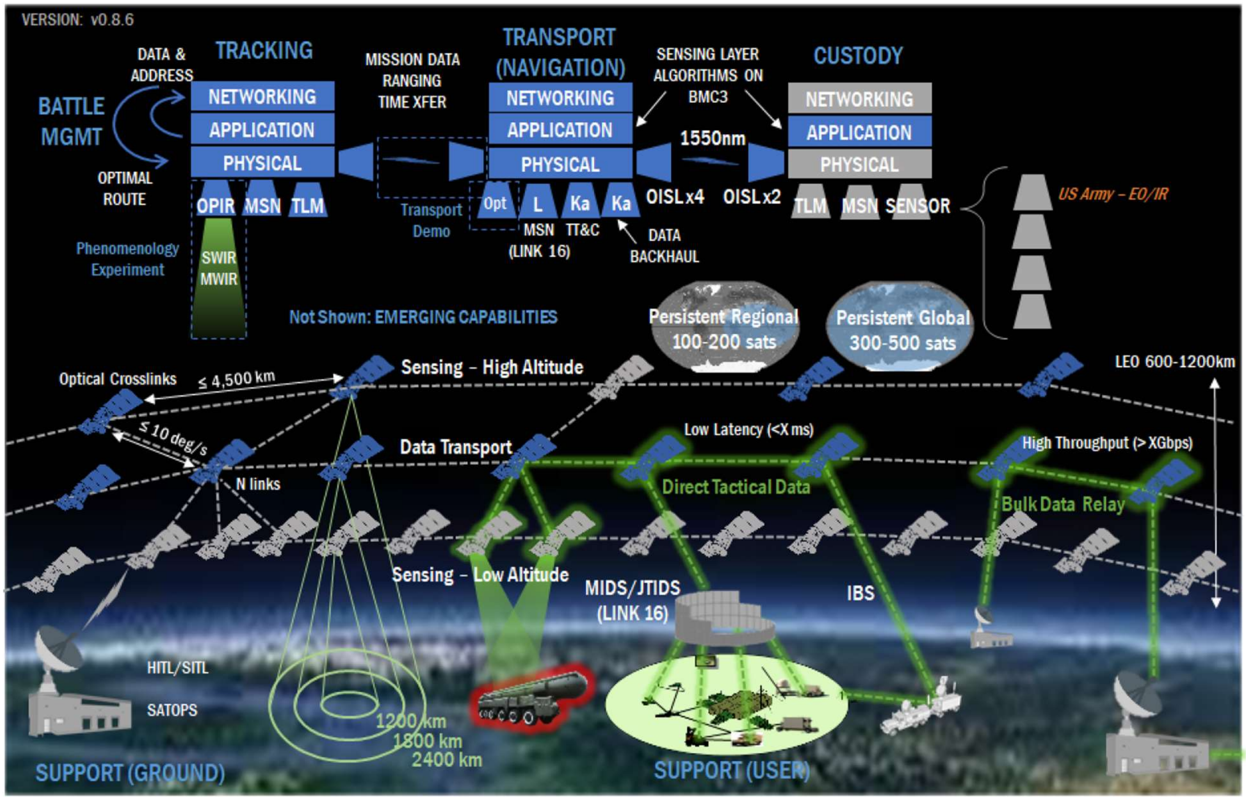

Figure 3: Objective Space Development Agency Architecture Supporting Space Support to Transformative Warfare (SS-TW)[48]

system architectures, and their associated acquisition strategies, represent a radical departure from traditional space system acquisitions. The USSF and DoD need to be proactive in supporting these new concepts and strategies while overcoming entrenched executive branch bureaucracies, Congress, and the old-space industrial base.

The USSF can potentially leverage the small satellite mass manufacturing practices of the burgeoning commercial production lines, including potentially hosting payloads and supplementing existing missions. It could also pursue this type of architecture via traditional defense primes. The small satellite mass manufacturing technique benefits the DoD because it helps overcome the problem of adversaries developing threats faster than the U.S. can deploy responsive space-based capabilities. The resulting architecture is thus designed to better overcome threats, ensure survivability, and expedite reconstitution. This promises to improve both deterrence and warfighting options in space.

Satellite services tied to emerging missions – Not fully established. Several efforts are underway to develop small satellite constellations that provide ubiquitous satellite voice and data services. These efforts could provide a significant boost for space-based systems in competition against traditional cellular service providers. While the providers of the small satellite constellations are not traditional players in the satellite communications industry, the current market participants are aggressively pursuing market expansion in the aviation sector with in-flight wi-fi. There is significant commercial interest in the idea of using smaller satellites for pLEO constellations, but it is also fraught with challenges. Achieving a return on invested capital for these concepts is proving challenging. The small satellite company OneWeb recently declared bankruptcy intensifying concern as to the viability of this sector. In February 2020, Elon

Musk stated that all satellite communication companies eventually went through bankruptcy.[49] SpaceX, SpaceX's subsidiary Starlink, and Blue Origin are privately funded by billionaires, which may prove to be the only viable way for these types of companies to survive. However, if this capability is core to the future of the USSF, then adequate long-term government R&D funding and rapid and responsive acquisition processes will be needed to build and support this emerging industrial base.

Acquisition factors tied to emerging missions. The 2017 National Security Strategy (NSS) calls on the DoD to improve its space architecture resiliency and to promote space commerce.[50] These two goals can be accomplished in parallel by coordinating with commercial space companies and collaborating, where it serves national security needs within the USSF budget. The widely publicized pLEO constellations currently being designed and fielded to deliver broadband internet from space offer a great example of a promising public-private partnership. Not only has the DoD engaged early in the design and development cycle with the SpaceX Starlink constellation team, but an interview with the Defense Experimentation Using Commercial Space Internet Chief Scientist, Dr. Greg Spanjers, confirmed the DoD has contracts and discussions in place with each potential pLEO satellite constellation operator, which supports the mission of SS-TW.[51] Close collaboration and seed funding early in the development process make the DoD a desirable partner for commercial entities. It offers the DoD an opportunity to collaborate with industry on satellite design and capability trade-offs without imposing significant impacts on cost, schedule, or performance. Early input provides the DoD with an opportunity to leverage dual-use technology at a lower price point, vice forcing expensive DoD requirements onto existing commercial platform post-production.

NON-MATERIEL SOLUTIONS: DETERRENCE, BURDEN SHARING & CHALLENGES

The previous sections of the report focused on materiel solutions for closing gaps between the prioritized mission strategy (Ends -- as represented in the five SMAs in Table 1) and the resourcing strategy (Ways and Means -- as represented by space systems required, budgets, and acquisition and industrial base factors in Table 1 and Table 2). However, it is also important to consider non-materiel and outsource solutions among the potential Ways and Means available to the U.S. national security space community. This section examines two issues, the utility of deterrence and the role of burden-sharing among civil space agencies, commercial actors, and allies. Each has the potential to shape and add value to the SMAs while simultaneously introducing challenges.

Deterrence: Space domain deterrence is complementary to Space Domain Superiority (DS-SF), the first priority SMA in Table 1. Effective deterrence in the space domain could lower the need for materiel solutions, or shift the balance between materiel solutions among the SMAs, depending on the deterrence approach used. For example, the history of the Cold War demonstrated that clearly designating certain U.S. space platforms as redline triggers for global thermonuclear war has a deterrent effect on attacks against those space systems. Thus, in the future, keeping the Space Support to the Nuclear Mission (SS-NM) as a separate SMA may have deterrent value in its own right. In addition, explicit disaggregation of NM-specific satellite payloads onto NM-only space platforms may further strengthen the deterrent effect for those systems. This could have real value to clarify requirements and acquisition strategies for USSF and strengthen and clarify doctrine and strategy for USSTRATCOM and the nuclear deterrence enterprise.

The value of deterrence for space warfighters in conventional conflicts is an open question in the coming era. To be effective, deterrence measures must be accurately communicated to adversaries, they must be clearly understood, the consequences declared must represent unacceptable costs, and the adversary must genuinely believe deterrence measures will be employed.[52] For the last step to be credible in a conventional conflict, it is necessary for the U.S. to have the unambiguous ability to attribute responsibility for attacks on its space assets. However, trustworthy attribution requires a not-yet-fully-fielded architecture for space domain awareness. This domain awareness architecture requires expensive and specialized ground and space-based systems. Further, to achieve attributability, the overall space domain awareness ecosystem must go beyond the ability to detect attacks. There must also be tried-and-true intelligence methodologies to interpret activities and adversary intent, and settled doctrine and policy for response options. Unfortunately, most of the elements in this awareness ecosystem remain in their infancy. Consequently, the current utility of space deterrence for conventional conflicts is debatable.

Burden-Sharing: At the same time, space domain awareness capabilities have utility beyond facilitating attack attribution. Many of the technologies that make awareness possible for the military also have utility to the civil and commercial space communities, in the form of Space Traffic Management (STM). This reality introduces opportunities for the USSF to engage in burden-sharing for the investment required for space domain awareness with civil space agencies, commercial actors, and allies.

Civil Space Agencies: When the White House issued Space Policy Directive Three (SPD-3) in June 2018, it charged the DoC to lead a coordinated effort with the DoD, Department of Transportation (DoT), and NASA to develop a plan for providing basic space situational awareness (SSA) data and STM services. The spirit of this directive was to remove routine SSA and STM out of the military and into a civil space agency, freeing the USSF to focus on military-centric missions such as intelligence and warfighting. Yet, SSA and STM are inextricably tied to the DS-SF mission area. The USSF cannot achieve space superiority without full situational awareness of the domain. Hence, cooperation with the DoC is a complementary means upon which the USSF can achieve its ends of space superiority. Since the SPD-3 was issued, the DoC's progress has been limited due to a lack of resources. Nonetheless, the DoC has continued to plan for SSA and STM with its limited resources and has considered commercial solutions. In the near term, the DoC's ability to enable the USSF to achieve space superiority will be extremely limited.

Commercial Actors: Within the space industrial base there are several commercial firms the DoC could potentially partner with to achieve the objectives outlined in SPD-3. For example, Analytical Graphics Incorporated (AGI) offers a subscription-based service to a well-developed commercial SSA database.[53] This commercial capability is achieved through AGI's Commercial Space Operations Center (ComSpOC). Since 2014, this service has grown in capacity and capability, tracking over 9,000 publicly cataloged objects in LEO, Medium Earth Orbit (MEO), Highly Elliptical Orbit (HEO), and GEO. Although not a silver bullet, such a firm and its expansive service could potentially fill a gap between mission strategy and resourcing strategy for the DoC to accomplish its objectives, while simultaneously enabling the USSF to offset costs in its pursuit of space superiority.

Alliances: The United States has an extensive network of allies and partners who have collaborated to advance SSA and STM. For example, the European Union (EU) has initiated several space-centric projects in recent years that could potentially enhance the USSF's ability to achieve space superiority. One such initiative is the European Military Space Surveillance Awareness Network (EU-SSA-N) project. This Italy and France co-led endeavor calls for developing an autonomous, sovereign EU military SSA capability that is interoperable, integrated, and harmonized with the EU Space Surveillance and Tracking (SST) Support Framework.[54] Together, the EU-SSA-N and SST, will detect, catalog, and predict movements of space objects and debris orbiting the earth and alert spacecraft operators to mitigate the risk of collision.[55] If the United States partnered with the EU on the EU-SSA-N project, the USSF could advance its ends along with several SMAs, reallocate STM funds towards military-centric missions, and lower the need for organic material solutions.

The U.S. has also forged close working relationships with foreign space agencies promoting burden-sharing for the expansion of the ISS. Among those key foreign space programs is the Japanese Aerospace Exploration Agency (JAXA). JAXA has evolved into a hybrid space agency that now manages commercial and scientific programs, as well as close coordination for military operations with Japan's Ministry of Defense (MoD). Japan's efforts to develop its military space capabilities stem from at least three main security objectives: (1) to bolster its independent reconnaissance capability in regard to key threats, such as North Korea and China; (2) to facilitate communications with ships and troops deployed overseas on UN missions or mandates; and (3) to support its growing activities in the area of missile defense, which it officially joined with the United States in 2003.[56] These objectives complement primary USSF missions.

After the January 2007 Chinese ASAT test, Japan was the only country to categorize Beijing's dangerous act as a violation of the Outer Space Treaty. Specifically, Japanese Prime Minister Shinzo Abe referred to Article IX of the treaty, which prohibits activities that could contaminate the space environment.[57] The counterspace threat demonstrated by China is something that jeopardizes both Japanese and American space assets. The USSF should work in close coordination with Japan's MoD and JAXA to develop innovative methods to deal with and defend against emerging counterspace threats. Another JAXA proposal is the deployment of an early-warning satellite in GEO to monitor North Korea for missile launches. This is yet another capability that the USSF could facilitate in close coordination with their Japanese counterparts.

Challenges: There are potential risks and tensions that must be considered when building or leveraging alliances, coalitions, or partnerships to deter adversaries in the space domain. First, sovereign nations will naturally prefer to grow their national defense industrial base versus that of its partner. Second, nations may be reluctant to share their vulnerabilities, even with their most trusted allies. Third, parties may pursue dual-use space-based platforms creating entanglement between civil, commercial, and military applications. Fourth, the fear of technology proliferation or intellectual property theft may inhibit an alliance, coalition, or partnership from launching advanced space-based platforms to deter their common adversaries. Each of these risks must be considered when developing a global strategy, norms, and governance. The benefits of continued cooperation with the U.S's trusted partners are significant, making these challenge considerations low risk to U.S. national security.

Additionally, global norms and governance contribute to the overall success of non-material solutions. Three factors challenge the advancement of global norms and governance.

First, it is difficult to attribute the violation of space norms or laws to a specific state or non-state actor. Second, if a violation was attributable to an entity, there is no significant mechanism in place to enforce such norms or laws. Third, the most advanced space-faring nations lack an incentive to promote norms and governance in the space domain. The U.S. must take a leadership role in future governance endeavors on a global scale. The strong alliances established for common purposes will aid in developing global governance where needed and promote more unified global policy norms.

Finally, the U.S. must continue to cultivate relationships with countries where it has not cemented enduring relationships. To this end, the U.S. must carefully manage the delicate balance between the ambitions of its potential allies and partners, and the relationship between these countries and great power competitors. First, the U.S. is developing relationships with India for space domain endeavors, yet there does not appear to be a strong strategic vision between these two democracies. The establishment of clear goals for the benefit of both nations would enhance the ability of the U.S. to rely upon India in space related issues and would enhance the overall deterrence posture of both in this region. Another aspect to consider is how Russia plays into space with respect to great power competition. Unlike the U.S. and Europe, Russia is not economically dependent on space, yet Russia maintains the third largest military satellite fleet in orbit with approximately 100 units.[58] At the same time, the U.S. participates with Russia on cooperative interests such as the ISS. This mixture of knowledge sharing and military tension contributes to international challenges by driving the need for domain superiority while simultaneously advancing scientific or practical matters.

STAKEHOLDER & POLITICAL ANALYSIS

As presented above, the 2020 SPC-IS seminar argues the future viability of the entire National Security Space enterprise depends on rapidly achieving space Domain Superiority as the first priority (DS-SF in Table 1). Similar to the challenges that the nascent Air Force faced in 1947, the birth of the USSF for triggered new inter-service and inter-agency rivalries based around resourcing for critical legacy missions and new space superiority requirements. This dilemma is exasperated because the USSF has a wide breadth of responsibility without full authority to resource or execute those responsibilities. Even with USSF established, there remain roughly 60 National Security Space stakeholder organizations, eight of whom have authority to procure material solutions for space systems, and six of whom have a responsibility in setting requirements. The USSF faces significant headwinds in consolidating space forces from across the National Security Space enterprise and streamlining procurement and requirements processes.

Inter-Service Challenges. A fundamental challenge for the USSF is uncertainty over exactly how two key Title-10 organizations will function within the USSF; the SpRCO and the SDA. These agencies have budget and acquisition responsibilities for two of the top three Space Mission Areas in Table 1 and Table 2 (*Domain Superiority*, DS-SF and *Space Support to Transformative Warfare*, SS-TW). It is imperative that plans for integrating these organizations inside the USSF move forward as planned. This will reinforce the consolidation of missions, streamline the funding sources, and reinforce the legislative actions of the NDAA 2020.

It is useful to consider that the five major SMAs will evolve over time. For a "still-shot" picture of the present, the static nature of Table 1 makes sense, depicting five distinct Ends for SMAs. It is also sensible for the Ways and Means on the right part of the table to be divided across distinct agencies, budgets, and established industrial players who provide distinct space platforms. However, if one imagines how things will evolve in the future, it is clear that to achieve the five Ends represented by the SMAs, it will be necessary to move away from the platform-centric acquisition approaches of the past, toward an architecture-centric future.

This transformation will require many trade-offs across the entire landscape of Ways and Means. Such trades can only be realistically achieved with a USSF in control as a single consolidated Title-10 military service. The first set of trade-offs that must be considered is between the space *Domain Superiority* (DS-SF) mission area and the *Space Support to Legacy Title-10* (SS-T10) mission area. However, at this moment, the budgets and the acquisition leads, for these two SMAs, are not consolidated under USSF. The SpRCO must be moved directly into the USSF as soon as possible, to enable effective rationalization of mission and resourcing strategies at the service chief level.

Another argument in favor of the overall goal of consolidating budget and acquisition authorities under the USSF is that space procurement budgets tend to be dominated by a few major space systems. This is important when one considers the tough process of prioritizing limited resources and limited funding streams. When a few major programs dominate the available budgets, and those few spans too many different agencies, the challenges of making trade-offs to pursue future strategies are amplified. Budgets that fall inside the portfolio of the same acquisition authority created more trade space.

Future USSF authority could be further compromised if the planned transition of space-related offices and functions from the Army and Navy do not proceed smoothly. In order for the USSF to succeed, the DoD and Congress must enforce alignment of the new service's authorities with its responsibilities, and place budget authority for all major Title-10 space programs under the USSF. As previously discussed concerning the SpRCO and SDA, the same arguments apply to the question of Army and Navy cooperation. This is a necessary step going forward, to consolidate all service requirements, eliminate unnecessary redundancies, and especially to allow for intelligent trades as the enterprise moves toward space support to transformative warfare strategies.

Inter-Agency Analysis. Beyond DoD issues, interagency considerations also arise as challenges and opportunities for USSF. Chief among these is the government-wide strategies for SSA and STM since these are tightly linked to the USSF mission for Space Domain Superiority. STM has been the responsibility of DoD, with some participation by the commercial space industry and allies. The shift of responsibility to DoC presents an opportunity for both DoD and DoC to collaborate and convince Congress to provide the necessary funding to invest in the commercial sector and maximize these unique capabilities.

The DoC Office of Space Commerce, though small, has the growing expertise to build upon. It already promotes the advancement of U.S. geospatial technologies in cooperation with relevant interagency working groups. It also provides support to all Federal Government organizations working on space-based PNT policy, including the National Coordination Office for Space-Based Precision, Navigation, and Timing. Because these primary functions of the Office of Space Commerce directly impact both DoD and DoC space operations, there are ample justifications that could be proposed to Congress for an increased budget request to accelerate the intent of SPD-3.

Inter-National Analysis. The UN's Outer Space Treaty of 1967 set the original framework for nation-state behavior and international cooperation in space. It promoted the peaceful use of space by prohibiting nations from putting nuclear weapons or weapons of mass destruction into orbit. This self-imposed constraint by signatory nations narrowed the scope of the threat the United States had to align its deterrence strategy and limited resources against. However, the treaty did not explicitly prohibit the weaponization of space.

As discussed in brief in the introduction, since the 1960s, when the treaty was signed, space has become highly commercialized, congested, and contested. The most obvious example was the January 2007 Chinese ASAT missile test, which left a 35,000-piece orbiting debris field that spread around the globe and instituted the era of space as a warfighting domain.[59] Many other examples exist. As recently as January 2020, a pair of Russian "nesting doll" satellites uncoupled, maneuvered behind a U.S. National Reconnaissance Agency (NRO) satellite, and followed it for several weeks. These actions highlight the growing concern that U.S. adversaries are expanding their capabilities in outer space beyond peaceful purposes and beginning to weaponize space.

One could argue that an updated international space treaty, or some type of international code of conduct for nation-state behavior in space, could potentially enable the USSF to narrow the scope of its strategy and limited resources to align against it. For example, any international effort to standardize STM or SSA systems would potentially assist with the USSF's SDA priority, helping to facilitate their ability to achieve Space Domain Superiority. However, this approach also opens the door to negative effects on U.S. national security. Standardizing space operations amongst the international community could constrain the USSF from developing effective space control mission doctrine, and thus complicate acquisition strategies for the emerging mission areas of DS-SF, and SS-TW. It could also harm SS-T10 and SS-NM as they evolve more toward an architecture-based future. Balancing the benefits of improved global SSA and STM, with the potential downside of degraded SMAs, is tricky. If the United States were to lead or encourage an international effort to update or adopt global norms in space domain, it would have to do so only in a way that allows leverage to shape such norms in a manner that will enable the USSF to achieve its desired national security space ends.

Industry Stakes in USSF Strategies. Commercial space firms complicate the issues facing USSF, as new technologies and new business models blur the lines of distinction between military, civil, and commercial space operations. The various government agencies with responsibility in space operations will need to adapt to the creative ways the space industry is developing. One example is SATCOM, which was historically segmented into a variety of capabilities based on bandwidth allocation and satellite design. The industry is mixing these segments and expanding services with a need for increased, high-speed bandwidth around the world at all times.[60,61] This crosses over regulatory domains and increases the risk of gray zone entanglement. This example of entanglement is one that may become commonplace, and the USSF must adapt to the new environments that develop and adopt new models of operation when they make sense for military applications. All SMAs could be impacted due to the diverse and potential ways entanglement may arise.

The commercial sector is looking to capitalize on the benefits of using smaller pLEO satellites. These satellites present an opportunity for the commercial sector and USSF because they are less expensive, lower human capital requirements, and can be mass-produced in a surge or mobilization situation. As mentioned in "Burden Sharing," these capabilities are in their early stages, and USSF could use its position as a buyer to invest in this market segment to stimulate growth that would be beneficial for both commercial and government entities. However, this increases the resource burdens on DoD when a space capability provided by industry cannot yet survive independently of the U.S. Government, and further jeopardizes potential advances for USSF in DS-SF, SS-T10, SS-TW, and SS-T50.

The launch segment of the space market sees growth in innovation and creativity to reduce the costs of launching an object into space. Furthermore, in an effort to support space tourism or trips to the moon and Mars, some firms are looking at how to use reusable rockets to get to space. These efforts in innovation have the potential to significantly reduce the price of launch. Also, on the commercial side, the need to send large satellites into space is declining. The U.S. government is the main buyer of launch services with heavy payloads, and therefore a much needed investor to sustain this segment as discussed in the launch industry for mature technologies above. If the commercial sector turns towards smaller satellites, then the launch sector could follow suit, leaving the heavy launch market completely. If heavy launch capabilities become a 'government only' endeavor, any SMA could see an increase in cost. These trends should be monitored closely by USSF for potential impact to budgets, schedules, and missions.

Industry will also be a partner in developing the new technologies required to engage in transformative warfare, along with national research laboratories, academic environments, and other government agencies. Not only must the USSF achieve DS-SF SMA, but it must also consider the future of warfare and how that may differ from the conventional warfare of today. The third SMA priority, SS-TW, looks at how space will be utilized in future conflicts. Near-term vision predicts enhanced missile warfare will have a large role, but the longer-term vision is less clear. The U.S. is a leader in R&D, especially at the basic and applied levels. Although some advances, such as the quantum-enabled Chinese satellite "Micius," have been made outside of the U.S., the U.S. must not lose sight of the long term game. Industry and national research labs are working together on the next breakthrough technologies. The USSF should continue support to these relationships, and work toward streamlining these new technologies into the orbital fleet to support these emerging industry markets.

Congressional Concerns. As the U.S. debt grows and mandatory spending requirements increase faster than the growth of the federal budget, budget-saving initiatives tend to target discretionary budget. All defense and non-defense agency spending are part of this vulnerable discretionary budget. The President's Budget FY 2021 (PB21) does increase the budgets for space programs among the government agencies. NASA has a proposed 12 percent increase for FY21 to $25.2 billion to accelerate the Artemis crewed lunar mission, and the DoC seeks $15 million and 15 positions to support the DoC Office of Space Commerce for the various requirements of SPD-3. If these requests are not fully funded by Congress, then the strategy will need to be rebalanced to accommodate the resources. One simple trade-off could be extending the target for crewed lunar missions by a year to 2025. Another potential solution to a less than ideal budget could be the DoD would continue to manage the STM mission until funding is in place for the DoC to take over.

The current will of Congress is supportive, as demonstrated through recent legislative activity (See Appendix C), yet the upcoming elections, coupled with the COVID-19 pandemic, may darken the horizon for space-based activities and funds. Congress is currently encouraging commercial activity by allowing NASA to open the International Space Station for commercial activities, allowing more space-based services, and supporting streamlined regulation (e.g., applications and licenses). Although Congress is supportive of space-based activities, the federal budget may go through a period of austerity as the U.S. teeters on the brink of recession. Typically, when Congress does not fully fund a program, it is because they do not support the strategy. In FY 2020, the President's budget requested $72.4M, but Congress only provided $40M, reinforcing to the DoD that Congress was not sure, at that time, of the roles and purpose of the USSF.[62] The USSF is scheduled to deliver additional reports this year to Congress to lay out its strategy and gain advocacy.

Although Congress is still uncertain of the mechanics of the future fit of USSF, the current administration is very supportive of the importance of space to DoD and industry. While the space domain is benefitting from the attention, the impending election cycle will impact how space is viewed in relative importance to another administration's priorities. Risk mitigation can be implemented by encouraging commercial development of products and services more able to operate independently from government interventions. Commercial development is likely to withstand any administration as its benefits are non-partisan. The House and the Senate are working legislative actions for the benefit of space commerce. These non-materiel actions support the space domain as a whole, and USSF should see tangential benefits from an improved industrial base.

CONCLUSION

The USSF is at a critical juncture in history. The fledgling Service should not be content to change reactively, but instead, it must revolutionize proactively. The prioritized space mission area framework presented in Table 1 provides a synthesized basis for discussing resourcing decisions facing the USSF. Foremost is the objective to achieve Space Domain Superiority: to protect and defend U.S. interests in space and negate adversary systems that place joint and coalition space systems at risk. Second is the need for the USSF to support the broader Joint Fight by securing and modernizing assets that are integral to the Title-10 missions (SS-T10). Next, it is imperative to transform the USSF towards an architecture supportive of future GIO concepts, via proliferated sensors in multiple orbits, and military-specific data transport layers (SS-TW). This is needed to create an internet-of-things in space to achieve a truly connected global force with the ability to connect senor-to-shooter in denied environments. Last, but not of lesser in importance is to continue critical support for nuclear (SS-NM) and Titel-50 intelligence activities (SS-T50), which are primarily resourced outside of the USSF.

To an extraordinary degree, the success of the USSF depends on rapid and continuous technological innovation, both to establish the DS-SF mission area, and to maintain the nation's SS-T10 competitive advantage. The USSF is on the path to creating the unified space mission authorities needed to accomplish rapid innovation through streamlined acquisition. The way forward may yet hold challenges in consolidating the space missions. Looming fiscal austerity will raise inter-service rivalries. Therefore, the USSF must conduct significant analysis prior to mission consolidation to fully understand the accompanying personnel and funding burdens, ensuring that all required resources transfer with new missions. Furthermore, the USSF Acquisition Corps must possess a flattened Milestone Decision Authority command chain rather than a hierarchical JCIDS process to avoid resistance to a traditionally complex approval process when procuring mature technology

Looking outward from USSF, the space industrial base plays an essential role in the success of the prioritized SMAs. The space industrial base has a mix of maturity levels, and the high priority SMAs have moderate to high risk due to these variances. Satellite manufacturing and satellite services in the industry need higher levels of maturity to support the USSF in DS-SF and SS-TW mission areas. This is not surprising, as both SMAs require the latest technology coupled with revolutionary capabilities that have yet to emerge in industry for the operational architectures the USSF will need to retain domain superiority. To achieve this technology dominance, the USSF must continue funding R&D at levels significantly higher than other Services.

Inter-governmental relationships will help encourage the space industrial base as well as support the USSF SMAs. The DoC is taking over the STM/SSA non-military missions, which will relieve USSF resources for military applications. NASA's Artemis program could advance technological breakthroughs for use in both military and commercial ventures. Also, commercial ventures are being encouraged by multiple government actions such as streamlining paperwork and allowing commercial activities on the ISS. The USSF will benefit from spurred space commerce by having a more robust industry from which to draw capability.

On the international stage, the U.S. should remain a leader in space matters. If the United States were to lead or encourage an international effort to update or adopt global norms in the space domain, it would have to do so in a way that allows leverage to shape such norms in a manner that will enable the USSF to achieve its desired national security space ends. Until the establishment of global governance, bi- and multi-lateral agreements will aid the U.S. in shepherding space matters in a favorable direction. One relationship that could provide the U.S. with additional benefits is with India. Although the U.S. and India have friendly space relations, there is room for improvement. The establishment of clear goals for the benefit of both nations would enhance the ability of the U.S. to cooperate with India on space-related issues and could enhance the overall deterrence posture of both in this region.

Congress has already voiced its support for space, both through proposed legislation and through NDAAs. In order for the USSF to succeed, the DoD and Congress must enforce alignment of the new service's authorities with its responsibilities, and place budget authority for all major Title-10 space programs under the USSF as outlined in the 2020 NDAA. It is almost certain that Congress will not increase discretionary spending in the coming years. The USSF should continue to release key strategic documents that continuously reaffirm the strategic importance of the space domain to the U.S. government and build support for future USSF missions.

The U.S., and the world, has passed the tipping point of space being a key element of national power. The President has set the U.S. on an upward trajectory with the creation of the USSF; however, success is not guaranteed. It will take a concentrated effort to overcome inter-service and intra-governmental rivalries, while simultaneously advocating for scarce resources with Congress. The SMA's presented in this paper provides a framework to identify, prioritize, advocate, and secure the resources and political advocacy for the USSF to succeed. If the USSF is successful, then the U.S. can secure its dominance in space and protect our national security for the future.

Appendix A: Mobilization

Industry Sector / Domain Definition

The global space industry has three segments: satellite manufacturing, launch providers, and space service providers (Figure 4).[63] Each market segment can be further refined into sub-specialties or market niches. Satellite manufacturers may specialize in assembling particular payloads, launch providers may specialize in the amount of mass their rockets can place into orbit, and space service providers tend to specialize in supplying a specific set of services to the market.

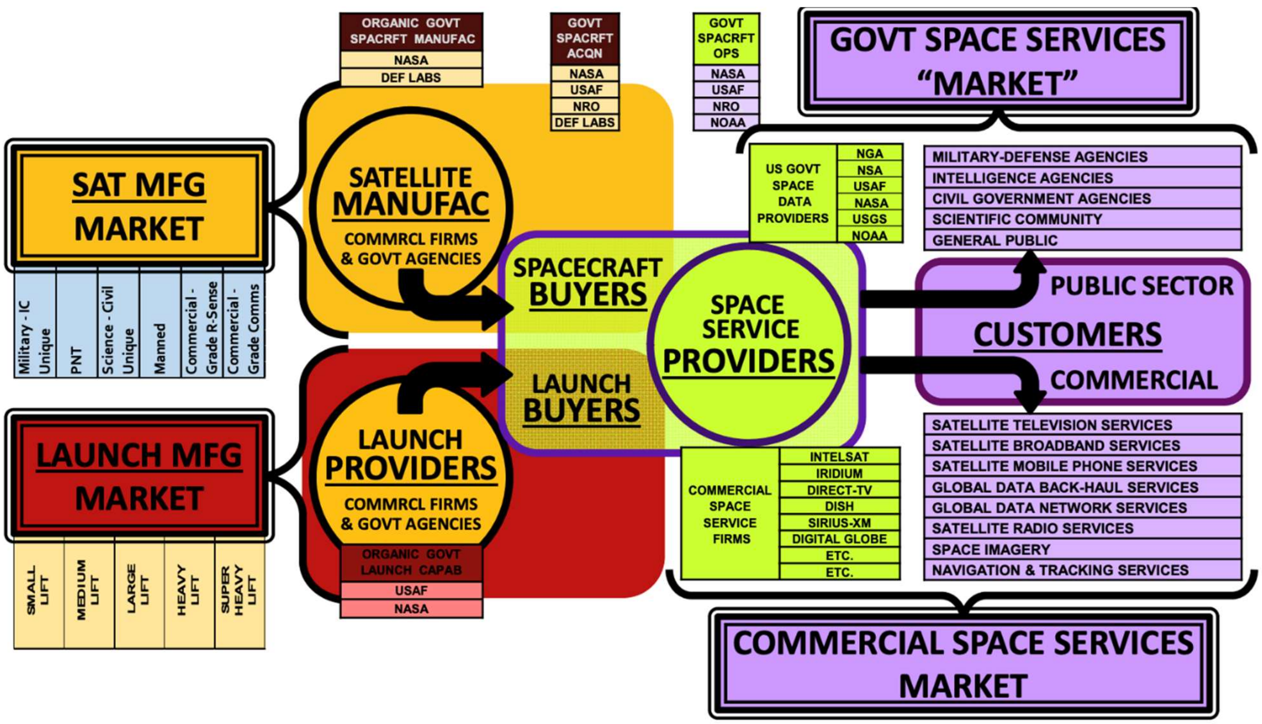

Figure 4. The Three Space Industry Market Sectors[64]

Figure 5 identifies these same market segments in terms of a value chain. Satellite manufacturing and launch providers are on the left side of the figure, labeled "infrastructure," and are upstream in the value chain. The companies in this market sector invest billions of dollars in fixed costs yet only capture a relatively small portion of the overall market. Another critical aspect of this portion of the value chain is that the production time for a single unit can be many years, which limits the industry's ability to surge or mobilize. Downstream space service providers need only invest tens to hundreds of millions of dollars in fixed costs to capture the most significant portion of the space market. Downstream firms can provide surge capacity quickly when called upon to do so by the DoD.

Satellite Manufactures: Due to the high level of specialization and knowledge required to meet stringent buyer performance requirements, satellite manufactures often become specialized in one, or a few, market segments such as communications or science missions. Companies must make significant investments in specialized manufacturing capabilities, such as large vacuum chambers, vibration, and acoustic testing apparatus, and exotic composites manufacturing. These substantial fixed costs form a high barrier to entry for firms wanting to enter the market, as do high costs of switching from one supplier to another. With a heavy reliance on government contracts, the satellite manufacturing market is primarily driven by government priorities.

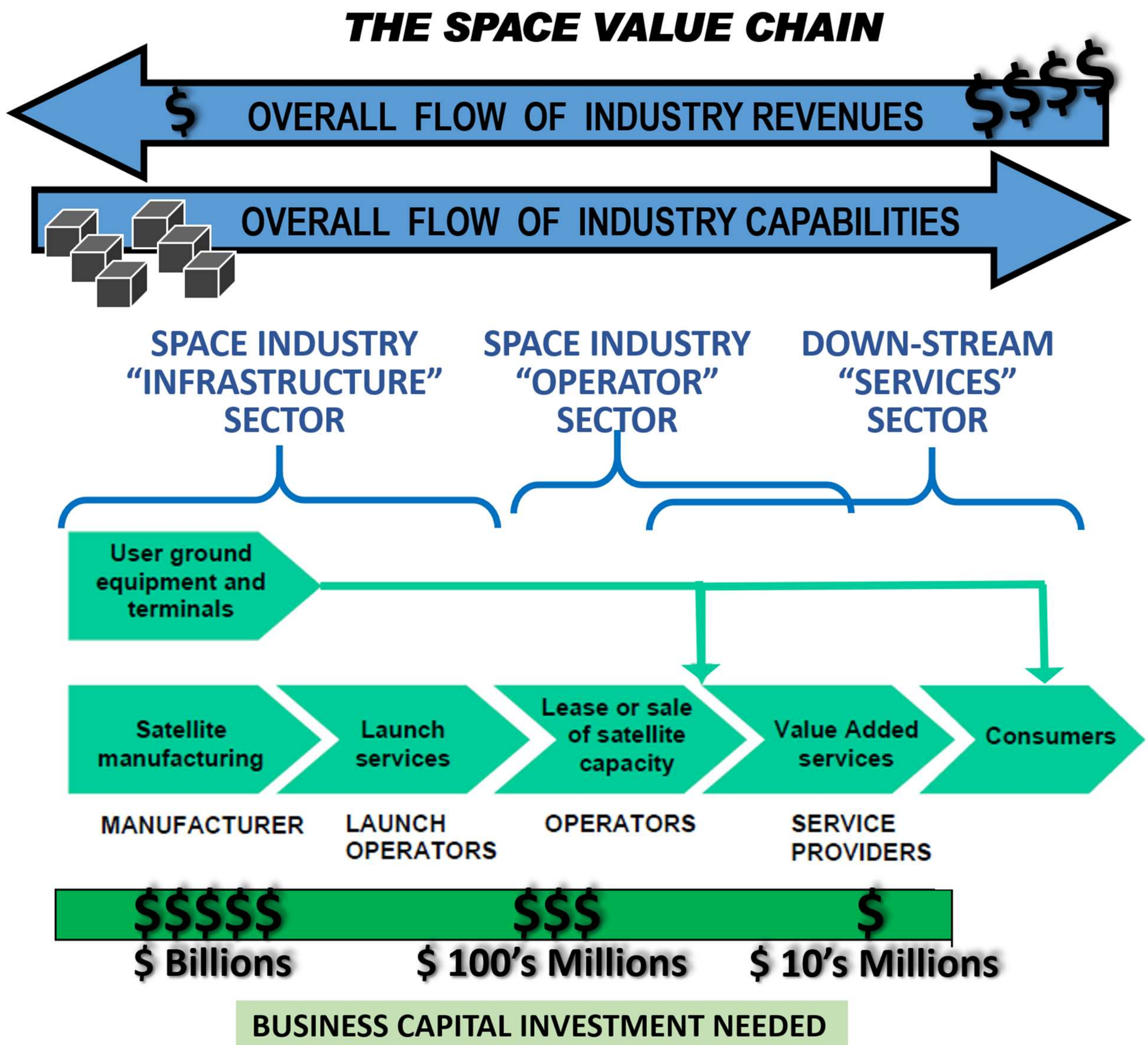

Figure 5. The Space Value Chain[65]

Note: Upstream firms invest billions to capture a small portion of market revenue, while downstream firms capture the largest portion of market revenue with a relatively modest level of investment.

Launch Providers: The launch provider market includes large and small liquid propulsion rockets, large and small solid rocket motors, electric propulsion, science and technology, and their associated test and evaluation facilities.[66] Launch provider customers include the DoD and its agencies, NASA, and space service providers such as Intelsat, Iridium, and Maxar Technologies.[67] The health of the launch provider industry relies heavily on government investment. USG and commercial defense customers account for 54 percent of the overall market. In the last 25 years, there has been significant market consolidation. For instance, solid rocket motor manufacturers decreased from six firms to two.[68]

Space Service Providers: The SIA estimated that the largest market segment within the global space economy is satellite services, with $126.5 billion in 2018 revenue.[69] Satellite communication services provide essential secure communication capabilities to users where no wireline or wireless base exists and makes up $124.4 billion (98 percent) of the overall satellite service provider market. Satellite communication services are further segregated into fixed, mobile, or broadcast services. The DoD is a heavy user of all three types of satellite communications services. Earth remote sensing satellite services involve the operation of satellite systems that measure energy reflected or emitted from the surface of the Earth and the post-processing of that data. The SIA estimates 2018 remote sensing revenue at $2.1 billion – only two percent of the overall satellite services market.[70] Ground station services provide satellite operators with the ability to issue command and control instructions to orbiting satellites and receive digital satellite payload data from the satellite via radio antennas located on every continent, including Antarctica. A robust network of ground stations provides multiple opportunities during the day to adjust satellite operations as required and to offload data from the satellite before on-board memory is exhausted. Finally, 2020 saw the birth of a new satellite-based service: the on-orbit satellite servicing of satellites located in geosynchronous orbit (GEO). A servicing satellite attaches itself to an on-orbit GEO satellite to provide propulsion and attitude control needed to extend on-orbit life or to move a defunct satellite (aka "space junk") to a graveyard orbit. Northrop Grumman's Mission Extension Vehicle-1 completed its first docking to a client satellite, Intelsat IS-901, on February 25, 2020.[71] Within the satellite service provider market, communications and remote sensing services have the most significant applicability to DoD missions.

Production Capability and Capacity for Surge

Satellite Manufacturers*:* The capacity for this market to surge production is currently LOW.

Satellite manufacturers tend to focus on specific market niches, where their accumulated engineering expertise is utilized to develop highly specialized products for demanding government customers. This specialization limits competition, as each provider will have difficultly acquiring the necessary breadth of specialists to compete outside of its niche. New market entrants such as Planet and OneWeb have up-ended the traditional satellite manufacturing model of manufacturing large, customized, hand-built, exquisite satellites. These two innovative companies employ an assembly-line production mindset for small, single-purpose satellites that operate in mega-constellations of hundreds or thousands of satellites. Organizations like the Space Development Agency (SDA) are seeking ways to leverage these new manufacturing concepts. Should the DoD take advantage of the assembly-line style of satellite manufacturing for future DoD satellites, the capacity for production surge improves.

Launch Service Providers: The capacity for this market to surge production is currently MODERATE.

U.S. law mandates that the DoD maintain contracts with at least two U.S. satellite launch providers capable of executing all required launch profiles, i.e., the ability to place a particular payload weight into a specific orbital regime.[72] A 2020 RAND study concluded that the number of projected DoD and commercial heavy-lift launches (i.e., market demand) over the next ten plus years results in such a low level of business that the demand can be satisfied by single launch provider (a single supplier). Since the DoD must contract with two suppliers per U.S. statute, both companies will have excess launch service capacity. This excess capacity provides the means to surge production if required.

Satellite Service Providers: The capacity for this market surge "production" is HIGH.

A primary reason that the downstream portion of the space economy is effective in meeting DoD surge requirements is that the equipment necessary to meet the increased need is already present at the time of increased demand. Capability and capacity developed to address the commercial market are simply repurposed to address military requirements. With forethought, the DoD can establish emergency-service contracts with select satellite service providers for communications, remote sensing, and ground stations in advance of need, complete with pre-negotiated terms, conditions, and fees to enable rapid surge when required. This surge model works well until the excess, or repurposed commercial service capacity is entirely consumed by DoD demand. At this point, further surge can only be accomplished by mobilizing the satellite manufacturing and launch provider industries.

Alternate Mobilization Models

The Department of Defense often repurposes commercial capabilities to address organic capacity shortfalls. The Air Force operates the Civil Reserve Air Fleet (CRAF), where commercial airlines voluntarily pledge aircraft to the program, ready for activation when needed. In return, the federal government makes all of its peacetime airlift business available to commercial airlines that volunteer aircraft to the CRAF. U.S. Transportation Command (USTRANSCOM) operates the Ready Reserve Force (RRF), a reserve of approximately 45 ships, able to set sail worldwide with five to ten days' notice. The Army operates the Logistics Civil Augmentation Program (LOGCAP), where contractors provide theater sustainment, engineering, and base operations support services along with the ability to respond to global contingency and non-contingency missions quickly.

These same models can be used to augment many of the space-based capabilities required to execute joint force missions. models for six space market sectors. In the table, green checkmarks indicate that the model has significant merit for the industry segment. Red crosses indicate that the model has poor merit for the industry segment. Yellow ellipses indicate that the model has moderate merit for the industry segment. The following conclusions can be drawn from this table: (1) mobilization models, with the exception for RRF in unique cases, have little applicability in the satellite manufacturing and launch market segments. These two segments reside in the upstream portion of the value chain where high fixed infrastructure costs make it difficult for companies to extract value; (2) the CRAF and LOGCAP mobilization models have greater applicability in the downstream services such as communications, remote sensing, satellite servicing, and ground stations; (3) the LOGCAP mobilization model proved to be useful across many downstream market segments of the space industrial base; and (4) the best use of the RRF mobilization model is in the remote sensing market, especially with regards to mobilizing small satellite imaging capacity.

Table 4 summarizes the applicability of the three mobilization models for six space market sectors. In the table, green checkmarks indicate that the model has significant merit for the industry segment. Red crosses indicate that the model has poor merit for the industry segment. Yellow ellipses indicate that the model has moderate merit for the industry segment. The following conclusions can be drawn from this table: (1) mobilization models, with the exception for RRF in unique cases, have little applicability in the satellite manufacturing and launch market segments. These two segments reside in the upstream portion of the value chain where high fixed infrastructure costs make it difficult for companies to extract value; (2) the CRAF and LOGCAP mobilization models have greater applicability in the downstream services such as communications, remote sensing, satellite servicing, and ground stations; (3) the LOGCAP mobilization model proved to be useful across many downstream market segments of the space industrial base; and (4) the best use of the RRF mobilization model is in the remote sensing market, especially with regards to mobilizing small satellite imaging capacity.

Table 4: Overall Applicability of Mobilization Models per Space Industry Segment

	Mobilization Model		
Industry Sector	Civil Reserve Air Fleet	Ready Reserve Force	Logistics Civil Augmentation Program
Satellite Manufacturing	✗	…	✗
Launch	✗	…	✗
Communications	✓	…	✓
Remote Sensing	…	✓	✓
Satellite Servicing	…	…	✓
Ground Stations	✓	✗	✓

Note: Green checkmarks indicate that the model has significant merit for the industry segment. Red crosses indicate that the model has poor merit for the industry segment. Yellow ellipses indicate that the model has moderate merit for the industry segment.

As mentioned earlier, the primary reason that the downstream portion of the space economy is effective in meeting military surge and mobilization requirements is that the equipment necessary to meet the increased need is already present at the time of increased demand. Capability and capacity developed to address the commercial market are simply repurposed to address military requirements. The more successful mobilization models do not need to wait for manufacturing to occur to meet surge demands. For space capabilities such as satellite communications, remote sensing, and ground station services, the capacity to meet government surge and mobilization requirements is already a part of the commercial space economy. The LOGCAP model proved to be an effective mobilization model for multiple space industry market sectors. While LOGCAP contract values can run into the hundreds of millions to billions of dollars annually, LOGCAP contracts are proven, cost-effective solutions that can be used to address shortfalls in government-owned and operated space mission capabilities and capacity.[73]

Nevertheless, certain aspects of the upstream satellite manufacturing industrial base and domestic launch capabilities remain fragile, and the mobilization models reviewed in this analysis do little to address this industrial base concern. Since satellite manufacturing and launch reside in the upstream portion of the value chain, high fixed infrastructure costs dominate the profitability equation. Mobilization techniques such as Defense Production Act (DPA) Title I prioritization and Title III production capacity expansion may be the only readily available means to expand the nation's production capacity for these two market sectors. New market entrants such as SpaceX and Rocket Labs who employ state-of-the-art rocket manufacturing techniques may be able to alter the value equation, which could enhance the applicability of the RRF mobilization model for launch services. Regardless of how it is accomplished, the nation's ability to mobilize the space industrial base strengthens its ability to counter the actions of great power competitors seeking to deny U.S. advantage in the space warfighting domain.

Supply Chain Resiliency

According to the 2018 Industrial Capabilities Annual Report to Congress, the leading risks and vulnerabilities of concern to the national security space industrial base are aerospace structures and fibers, radiation-hardened microelectronics, radiation testing, qualification facilities, and satellite components and assemblies.[74] An inter-agency task force subsequently reported to President Donald Trump:

> The DoD space industrial base is a niche market with very specialized and capital intensive capabilities that are not efficiently managed through individual program investments. Many systems currently in planning and development rely on dated technology, skills, and fragile sources. Individual programs are reluctant to invest in and qualify new technology and sources, creating a need to sustain fragile domestic sources and to qualify new technologies and sources for next-generation systems, which are essential to address ever-increasing threats in the space domain.[75]

The report also concluded that commercial space systems tend to rely on wholesale replacement of malfunctioning systems while national security enterprise favors deploying long-term, mission-capable systems.[76] With commercially-available technology becoming ever more capable, perhaps now is the time for the DoD to shift its focus to deploying less complex space systems that are replaced with newer technology on a more frequent basis.

International Security of Supply Agreements

The bi-lateral security of supply agreements have little effect in mitigating supplier risks associated with the U.S. space industrial base for one primary reason: the nine countries (Australia, Canada, Finland, Italy, The Netherlands, Norway, Spain, Sweden, and United Kingdom) and identified companies are not significant sources of the critical components identified above in section Supply Chain Resiliency. One possible exception is the Nammo corporation of Norway and its rocket propulsion line of business. However, Nammo supports the U.S. space market via its wholly-owned U.S. subsidiary, Nammo Defense Systems.

Expansion of International Security of Supply Agreements

Aerospace structures and fibers, radiation, and qualification testing facilities and some subset of satellite component and assembly production are possible elements that can be added to the current international security of supply agreements to address U.S. manufacturing shortfalls. The current "Five-eye" security arrangement cohort (Australia, Canada, New Zealand, United Kingdom, U.S.) is a logical suite of countries with whom to begin distributed production discussions. Due to the sensitive nature of radiation-hardened microelectronics, the U.S. will likely retain an entirely domestic production base for these particular items.

Mobilization Challenges

Workforce: The U.S. space industrial base relies upon a workforce with high-demand skills in engineering, science, manufacturing, information technology, and cybersecurity. Department of Commerce and Government Accountability Office studies document a national shortage of Science, Technology, Engineering, and Mathematics (STEM) professionals in the space industry.[77,78,79] The shortage of STEM professionals results in cut-throat competition amongst space companies for this scarce resource. Compounding this shortage is the time required to obtain personnel security clearances to enable work on critical elements of the U.S. national security infrastructure. Public and private sector data identify the quickening retirement pace of space industry workers as another critical industrial base concern.[80,81]

Long lead items: The traditional space manufacturing process is long and complex. It can take over four years to manufacture a national security space satellite. Components must undergo extensive testing after manufacture, and multiple components feed into the production of sub-assemblies.[82] The sub-assemblies are then individually tested, and multiple sub-assemblies are put together to form an assembly, which is also thoroughly tested. Assemblies form sub-systems and sub-systems form systems, with layers and layers of further testing at each stage. The availability of the smallest components, such as floating-point gate arrays described above in the Supply Chain Resiliency section, can be a pacing function in the manufacture of sophisticated satellites. The customers, including DoD, may not have four-plus years to wait for a capability.

Planet and OneWeb exemplify an alternative manufacturing technique. These companies are capable of building a complete satellite in a single eight-hour shift. These small satellites are designed to last only two to three years in the harsh space environment. Large, complex satellites operating for over 15 years in space must withstand a constant radiation bath emanating from the sun. After Planet or OneWeb settle on a satellite's design, the firms create an assembly line to produce tens to hundreds of satellite clones. These companies accept that a small percentage of satellites may fail early in their projected life. Since the companies keep more satellites in orbit than required to meet minimum mission requirements, there is an on-orbit spare that is ready to take on the work of a failed satellite. The SDA is looking to mimic this highly resilient space architecture with its proliferated LEO constellation.

Capacity of private and public infrastructure: Except for a handful of small satellites built by military Service research and development laboratories each year, private industry manufactures most of the U.S. government's satellites. In 2018, approximately 75 percent of U.S. satellite manufacturing revenue came from U.S. government business, but roughly 60 percent of the satellites launched in 2018 were commercial satellites.[83] Commercial demand drives satellite production capacity; however, government business drives satellite revenue. The

U.S. government can take advantage of this commercial production capacity in times of national emergency.

The three major launch complexes in the U.S. at Cape Kennedy/Cape Canaveral, Vandenberg Air Force Base, and Wallops Island are government-owned facilities. Cape Kennedy and Wallops Island are Government-Owned, Contractor-Operated launch facilities. There is a growing number of minor public and private launch complexes holding Federal Aviation Administration (FAA) licenses to conduct space flight operations. The major launch complexes have supported approximately 20 launches per year for the past decade.[84]

Potential Applications of the Defense Production Act (DPA)

Congress enacted the DPA on September 8, 1950. The act contains seven individual titles that provide the President with authorities to control national economic policy, three of which remain active today. Title I permits the President to prioritize and allocate industrial resources. The President can demand that a company accept prioritized national defense contracts/orders over all other non-prioritized contracts/orders. Title III gives the President authorities to ensure that the U.S. has a sufficient supply of essential materials and goods for national defense through the use of financial incentives, including loan guarantees, loans, direct purchases, purchase commitments, and equipment purchases. Title VII describes the core responsibilities of the Committee on Foreign Investment in the United States (CFIUS) in addition to providing overall guidance in the use of the DPA.

DPA Title I has a potential application to the three space market sectors: satellite manufacturing, launch providers, and satellite service providers. In a time of national emergency, the President can force a launch service provider to manufacture a rocket ahead of other commercial or non-priority government orders. The instance of the government requisitioning a partially-completed rocket body for its use in a national emergency would be an interesting legal case unless an acceptable level of compensation with the losing party were negotiated. The government could also refuse, or revoke a company's FAA license to conduct launches, as a means of prioritizing launch services and access to space. Similarly, the government could use Title I to prioritize the manufacture of a government satellite, or prioritize government access to crucial, critical-path manufacturing facilities such as clean rooms, pressure chambers, and acoustic chambers. Finally, the President could use Title I authorities to prioritize government contracts for U.S. based satellite communication services. This action may not be very effective because many satellite communication service companies are headquartered overseas, beyond the executive branch's control.

By definition, DPA Title III has direct application to the two downstream sectors market sectors: launch and manufacturing. President Donald Trump made eleven Title III determinations in 2019, many of which have a direct relationship with launch and satellite manufacturing. These determinations cover chemicals used to make solid rocket motors and the separation and processing of rare earth elements necessary for microelectronic manufacture. The President's $181 million FY2021 DPA Title III budget request includes a variety of space-related items such as radiation-hardened digital and analog microelectronics, field-programmable gate arrays, trusted radiation-hardened microelectronics foundry, rare earth element processing, and critical chemicals for solid rocket motors.

The CFIUS, governed by DPA Title VII, has significant application to the U.S. space industrial base. Key U.S. space technologies are subject to International Traffic in Arms

Regulations (ITAR), which is a regulatory regime that restricts and controls the export of defense and military-related technologies to safeguard U.S. national security and further U.S. foreign policy objectives. CFIUS approval of the foreign acquisition of U.S. companies that produce ITAR-controlled products rarely occurs and only with stringent controls inserted into the corporate structure that prevents the flow of critical information and technology overseas.

Adequacy of Executive Order 13603

Section 201 of Executive Order 13603 provides authority to the Secretary of Commerce (SecCom) to require acceptance and priority performance of contracts or orders to promote national defense. However, the SecCom can only give such direction after the Secretary of Defense (SecDef) has decided that such action is required, per Section 202 of the order. This division of authorities has been adequate to implement priority ratings on critical DoD space-related contracts to date. Since the SecDef is the only administrator who can issue a DPA priority determination for space-related contracts, organizations such as NASA and NOAA must petition the SecDef to "lobby" SecCom for priority ratings for their space-related contracts when required.

Civilian Reserve Force

There is value in recruiting members from the space industry into a Civilian Reserve Force. Industry members would bring expertise in the design, manufacturing, and operations of proliferated constellations with hundreds or thousands of satellites. For example, the recently concluded Wideband Communication Services Analysis of Alternatives had difficulty assessing the capabilities of a proliferated wideband satellite communication architecture. In turn, Industry members would be exposed to emerging DoD space requirements. They can provide recommendations on how best to leverage burgeoning commercial small satellite production lines to host government payloads and use commercial capabilities to supplement existing government missions. A closer link between government and industry would help address the information gap coming from the rapid pace of change in commercial space markets.

Policy Recommendations

The USSF requires specialized capabilities in order to operate in America's newest warfighting domain effectively. The USSF must establish a mobilization capacity to augment its organic capabilities with capabilities provided by the private sector. The Service should consider LOGCAP, CRAF, and RRF as possible mobilization models. A robust commercial partnership ensures that the USSF can take advantage of the newest industry innovations while simultaneously avoiding expensive military-only procurement satellites and services.

The USSF must consider initiatives such as public-private partnerships and STEM outreach, which must begin today in order to address growing human capital concerns and prevent the U.S. from falling behind its great power competitors.

Appendix B: Porter's Diamond Analysis
Space Launch and Manufacturing Markets

Michael Porter's "Porter's Diamond" model of national advantage explains how nations develop a global competitive advantage in certain industries, based on competitiveness in four interrelated attributes. These are (1) firm strategy, structure, and rivalry, (2) factor (input) conditions, (3) demand conditions, and (4) related and supporting industries (Figure 6).[85] Porter's model asserts that a national environment that supports the "rapid accumulation of specialized assets and skills," has better processes and product insights, and pushes companies to "innovate and invest," is more competitive.[86] Correspondingly, a weakness in one determinant would constrain the industry's potential. This analysis of state-organized and non-state organized space sectors shows where the United States holds competitive advantages and how Great Power Competition intersects.

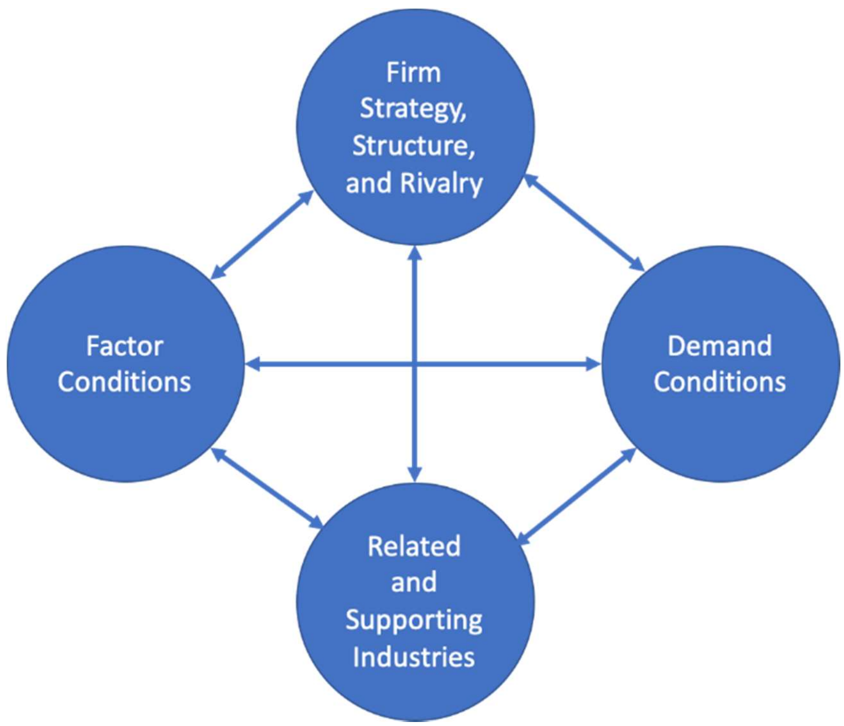

Figure 6. Porter's Diamond Model of National Advantage

Overview of Porter's Diamond Model[87]

Firm strategy, structure, and rivalry concentrates on the conditions governing how companies are created, organized, and managed, and the nature of rivalry to determine how domestic businesses develop and operate. [88] *Factor conditions* describe the various factors of production (such as physical and human resources) a nation has at its disposal to compete in an industry.[89] *Demand conditions* describe the nature of domestic demand for what the industry produces, such as whether the consumers are discriminating.[90] *Related and supporting industries* describe the status of national suppliers and related industries and whether they are internationally competitive. Porter emphasizes that governments can magnify competitiveness by encouraging change, promoting domestic rivalry, and stimulating innovation.[91]

State-Organized Sectors: U.S. Space Launch and Defense-Related Satellite Manufacturing

The U.S. Government (USG) comprised 77 percent of the domestic satellite manufacturing market (intelligence and defense platforms) and approximately 80 percent of the U.S. launch market in 2018.[92] These markets are highly concentrated. Launch vehicles for commercial space and defense use the same technology as missiles and are subject to tight export controls through International Traffic in Arms Regulations (ITAR). All launches of U.S. ITAR-controlled projects must be executed by U.S. launch service providers. Furthermore, the government protects the launch market through a funding mechanism that ensures there are at least two major launch providers in the market. Primarily driven by government priorities and protected by extensive government regulation, these markets operate as oligopolies. *Firm strategy, structure, and rivalry issues* decrease national competitiveness in these markets. Market entry is costly and complicated, and rivalry limited as firms cooperate to fulfill government contracts. The complexities of government contracts, clearances, and cybersecurity protocols challenge new entrants. Government contract requirements can stifle innovation. *Demand conditions* are driven by a monopsony buyer rather than free-market principles. USG-supported companies can become "hooked on the narcotic of government contracts or creeping industry protection," which takes away the challenges that drive innovation. Furthermore, USG-supported manufacturers tend to focus on specific market niches, where their accumulated engineering expertise can be utilized to develop highly specialized products for government customers. This specialization limits competition, as each provider will have significant difficultly acquiring the necessary breadth of specialists to compete outside of its niche. *Related and supporting industries* are also heavily regulated, including Berry Amendment restrictions, which require all strategic materials to be U.S.-sourced absent a waiver. In some cases, the launch industry must rely on single-source materials, decreasing market efficiency. Monopoly suppliers can control prices and squeeze the profitability of space manufacturers.

Non-State Organized Sectors: U.S. Commercial Satellite Manufacturing

In contrast to the government-focused space sector, the U.S. commercial-focused satellite manufacturing market has evolved into a highly competitive market and global leader. U.S. satellite manufacturing revenue accounted for 59 percent of global revenues in 2018, or $11.5 billion. This represented a 26 percent increase from 2017.[93] Reforms in 2013that authorized the removal of satellites and related items from the U.S. Munitions List (USML) and revised ITAR rules in 2014 ended a 15-year period during which nearly all U.S. satellites and components were controlled as defense articles. The move of satellite and related components from the USML to the Department of Commerce’s Control List (CCL) jumpstarted growth in the sector, including new entrants with innovative manufacturing techniques and value chain integration.

Firm strategy, structure, and rivalry are a competitive strength for the United States. Robust intellectual property rights (IPR) protections help stimulate R&D and capital investment in the sector. Domestic competition is vigorous and bold new market concepts such as mega-constellations for imaging and global internet services, as well as increasing production of small satellites have emerged. Sophisticated and demanding satellite buyers in the United States who lead global trends comprise competitive *demand conditions.* Among *related and supporting industries,* suppliers remain heavily regulated, but related industries are competitive and growing.

Factor Conditions

The United States holds an advantage in *factor conditions* across both sectors in its industry clusters. California and Colorado are home to business, government, and academic space industry clusters. Colorado has over 180 aerospace companies and 400 suppliers of space-related products and services.[94] California draws its human and intellectual capital from technology clusters such as Silicon Valley and is the world leader in space-related patents.[95] Emerging space companies are clustering around Cape Canaveral, Florida, which offers favorable tax laws. However, the space industry faces a national shortage of STEM professionals, and the number of students graduating with degrees in space-related technologies is insufficient.[96,97] Furthermore, across the space industry, more skilled labor is retiring than is entering the workforce, increasing the demand for qualified and skilled STEM graduates. Although the U.S. has increased its number of STEM graduates by 15 percent in the last ten years,[98] the distribution across the STEM fields is problematic – the space industry is academically underrepresented.

Great Power Competition

In the realm of state-organized space sectors, Porter's Diamond reveals that the United States and China have many similarities. China's space sector is largely state-subsidized. China is seeking a greater role in space and was the first to land on the dark side of the moon in 2019.[99] Although U.S. firm SpaceX led in the number of annual launches by a single company in 2018 (21 launches), China was the world leader for the number of launches by a nation.[100] In the commercial realm, China's interventionist government tendencies, which generally limit competition, are unlikely to help the sector obtain a competitive advantage. The sector is not seen as central to China's overall efforts in space. Non-state funded startups in China numbered 42 in 2018, but these companies did not have a clear business strategy.[101] China's reputation for technology theft could be a disincentive to companies considering starting up, for fear their innovations would not be protected, while the United States has some of the strongest protections for intellectual property rights in the world. The U.S. could maintain its competitive advantage by incentivizing competition through R&D funding, tax incentives, and innovation support and funding.

One area where the United States faces a competitive disadvantage with China is in the critical area of STEM human capital. China overtook the U.S. as the largest producer of doctoral degrees in the natural sciences and engineering in 2007 and has quadrupled the number of S&E degrees conferred since 2000. These degrees comprise nearly half of all bachelor's degrees awarded in China.[102] The USG can help bolster factor conditions for the industry by increasing funding to STEM outreach efforts, scholarships, low-interest loans, and grants for students pursuing crucial STEM degrees.

Industry clusters, such as the Shenzhen region's highly-successful "Silicon Valley of China," show the Chinese government's ability to spur economic growth through government policy focused on innovation.[103] However, the nature of innovation in the space industry is unlikely to lend itself to this type of model, and the United States will likely continue to lead in the commercial satellite market based on its innovation advantage.

Appendix C: Space Regulation, Policies, Governance, and Directives

Summary of Major Space Governance Instruments

Year	Title	Type	Jurisdiction
1967	Treaty on principles governing the activities of States in the exploration and use of outer space, including the Moon and Other Celestial Bodies	UN Multilateral Treaty	All ratifiers
1969	Agreement on the rescue of astronauts, the return of astronauts, and the return of objects launched into outer space	UN Multilateral Treaty	All ratifiers
1975	Convention on international liability for damage caused by space objects	UN Multilateral Treaty	All ratifiers
1976	Convention on registration of objects launched into outer space	UN Multilateral Treaty	All ratifiers
1984	Agreement governing the Activities of States on the Moon and Other Celestial Bodies	UN Multilateral Treaty	All ratifiers
2003	U.S. Commercial Remote Sensing Policy	Executive Order	U.S. only
2010	Space Debris Mitigation Guidelines of the Committee on the Peaceful Uses of Outer Space	UN Voluntary Guidelines	Not legally binding
2010	National Space Policy of the U.S.	Executive Order	U.S. only
2015	U.S. Commercial Space Launch Competitiveness Act	U.S. law	U.S. only
2017	Executive Order 13803. Reviving the National Space Council	Executive Order	U.S. Only
2017	Space Policy Directive-1, Reinvigorating America's Human Space Exploration Program	Executive Order	U.S. Only
2018	American Space Commerce Free Enterprise Act*	Passed by House of Representatives	U.S. Only
2018	Space Policy Directive-2, Streamlining Regulations on Commercial Use of Space	Executive Order	U.S. Only
2018	Space Policy Directive-3, National Space Traffic Management Policy	Executive Order	U.S. Only
2019	Space Policy Directive-4, Establishment of the United States Space Force (USSF)	Executive Order	U.S. Only
2019	Space Frontier Act*	Introduced in U.S. Senate	U.S. Only
2020	Executive Order 13914. Encouraging International Support for the Recovery and Use of Space Resources	Executive Order	U.S. Only

Appendix D: Definitions/Glossary of Acronyms

Definitions

Space industry – The space industry is a specialized sector within the aerospace and defense industry defined by manufacturing and service activities.

Space manufacturing sector – The space manufacturing sector includes firms that develop, produce, and sustain rocket launch vehicles, satellites, and space-related ground equipment.

Space services sector – The space services sector encompasses firms that use spacecraft to provide five primary services: (1) satellite telecommunications (SATCOM) services (network backhaul and direct-to-consumer); (2) space-based earth observation data products; (3) space-based science; (4) spacecraft ground operations services; and (5) space control.

Glossary of Acronyms

ASAT – Anti-satellite
CFIUS – Committee on Foreign Investment in the United States
COCOM – Component Commander
COVID-19 – Corona Virus Disease 2019
CR – Continuing Resolution
CRAF – Civil Reserve Air Fleet
DoC – Department of Commerce
DoD – Department of Defense
DPA – Defense Production Act
DS-SF – Domain Superiority for the Space Force
DSUM – Domain Superiority USSF Mission
ES – Eisenhower School
EU – European Union
EU-SSA-N – European Union Space Situational Awareness Network
FAA – Federal Aviation Administration
FCC – Federal Communications Commission
FY – Fiscal Year
FY22 – Fiscal Year 2022
FYDP – Future Years Defense Program
GEO – Geosynchronous Earth Orbit
GIO – Globally Integrated Operations
GPS – Global Positioning System
HEO – High Earth Orbit
HEO– Highly Elliptical Orbit
IC – Intelligence Community
ISS – International Space Station
ITAR – International Traffic in Arms Regulations
JAXA – Japan Aerospace Exploration Agency
JCIDS – Joint Capabilities Integration and Development System
LEO – Low Earth Orbit

LOGCAP – Logistics Civil Augmentation Program
MDA – Missile Defense Agency
MEO – Medium Earth Orbit
MFP – Major Force Program
MoD – Ministry of Defense
NASA – National Aeronautics and Space Administration
NATO – National Atlantic Treaty Organization
NDAA – National Defense Authorization Act
NDS – National Defense Strategy
NDU – National Defense University
NGA – National Geospatial-Intelligence Agency
NGSO – Non-Geostationary Orbit
NM – Nuclear Mission
NOAA – National Oceanic and Atmospheric Administration
NORAD – North American Aerospace Defense Command
NRO – National Reconnaissance Office
NSA – National Security Agency
NSS – National Security Strategy
O&M – Operations and Maintenance
ODNI - Office of the Director of National Intelligence
OPIR – Overhead Persistent Infrared
OSD – Office of the Secretary of Defense
PB – President's Budget
pLEO – Proliferated Low Earth Orbit
PNT – Positioning, Navigation, and Timing
PROC – Procurement
R&D – Research and Development
RDT&E – Research, Development, Testing, and Evaluation
RRF – Ready Reserve Force
SATCOM – Satellite Communication
SDA – Space Development Agency
SecCom – Secretary of Commerce
SecDef - Secretary of Defense
SIA – Satellite Industry Association
SMA – Space Mission Areas
SMC – Space and Missile Systems Center
SPC-IS – Space-Counterspace Industry Study
SPD – Space Policy Directive
SpRCO – Space Rapid Capabilities Office
SSA – Space Situational Awareness
SSJF – Space Support to the Joint Fight
SS-NM – Space Support for the Nuclear Mission
SS-NM – Space Support to the Nuclear Mission
SST – Space Surveillance and Tracking
SS-T10 – Space Support for the Title 10 Mission
SS-T50 – Space Support to Title-50 Mission

SS-TW – Space Support to Transformative Warfare
STEM – Science, Technology, Engineering, and Math
STM – Space Traffic Management
STS – Sensor to Shooter
TRL – Technology Readiness Level
TTPs – Technique, Tactics, and Procedures
TW-SS – Transformative Warfare Space Support
U.S. – United States
UN – United Nations
USDI – Undersecretary of Defense for Intelligence (USDI)
USML – United States Munitions List
USNORTHCOM – United States Northern Command
USSF – United States Space Force
USSPACECOM – Unites States Space Command
USSTRATCOM – United States Strategic Command
USTRANSCOM – United States Transportation Command
WTO – World Trade Organization

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