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THE STRATEGIC NECESSITY TO INTEGRATE COMMERCIAL IN-SPACE SERVICING, ASSEMBLY, AND MANUFACTURING (ISAM) INTO UNITED STATES SPACE FORCE CAPABILITIES

SPACE INDUSTRY STUDY
SEMINAR 13 GROUP RESEARCH PAPER

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The Dwight D. Eisenhower School
for National Security and Resource Strategy
National Defense University
Fort McNair, Washington, D.C. 20319-5062

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Executive Summary

The establishment of the U.S. Space Force (USSF) marks a pivotal shift in space operations for the United States and is a clear recognition of the increasing strategic, economic, and national security significance of space. The rapid evolution of the commercial space industry, particularly In-Space Servicing, Assembly, and Manufacturing (ISAM), presents opportunities for the USSF to leverage emerging capabilities to enhance U.S. and allied interests in space. Commercial ISAM capabilities, with their potential to extend the lifespan and expand the functionality of space assets, will be critical enablers of USSF space superiority missions vital to U.S. national security. The USSF must therefore prioritize investing with commercial firms to ensure the development of a mature and robust ISAM market, while also coordinating closely with allies, partners, and other U.S. government departments and agencies. By fostering the growth of the ISAM market, the USSF will reap long-term cost savings from broader commercial capabilities, enrich its relationships and burden sharing with U.S. allies and partners, and foster interagency cooperation to benefit American innovation and economic growth.

This report argues for the strategic necessity of integrating emerging commercial ISAM products and services with USSF capabilities. It begins with a discussion of the current strategic environment, highlighting how the People's Republic of China (PRC) and the Russian Federation are challenging U.S. space superiority and the variety of stakeholder interests related to the U.S. commercial space industry. It then evaluates recently released U.S. military commercial space strategies and the proposed FY2025 USSF budget. The following section highlights the importance of fostering the growth of new ISAM markets to enable the long-term success of the USSF's commercial integration efforts.

The final section offers a series of policy recommendations to facilitate the findings of this report, including the adjustment of future USSF resource allocations to capture cost savings; seeding the ISAM market to stimulate competition, innovation, and long-term growth; the creation of a Space Investment Fund; and the use of matching grants and expanded public-private partnerships. This report also recommends the USSF coordinate with other U.S. government departments and agencies proactively to advocate for more robust domestic ISAM regulatory reform and the adoption of international legal frameworks and standards consistent with U.S. best practices. By embracing these strategies, the USSF can maintain its competitive edge in space, ensuring it remains at the forefront of technological innovation and strategic capability in an increasingly contested domain.

Student Contributors and Faculty Advisors

Student Contributors

Col Gary Beisner – U.S. Air Force

CDR Peter Borszich – U.S. Navy

Col Jason Braun – U.S. Air Force

Mr. Scott Cameron – U.S. Agency for International Development

SSA Tina Chang – U.S. Department of Commerce

Lt Col Vivian Cochran – U.S. Army Reserve

Mr. William M. Coleman, IV – U.S. Department of State

Col Zachariah Corke – U.S. Army

Ms. Gretchen McKeever Cureton – U.S. Department of State

CDR Ryan DiPaolo – U.S. Navy

Lt Col Brandon Galindo – U.S. Space Force

Ms. Ulinda Harper – National Geospatial-Intelligence Agency

Col Jason Kendzierski – U.S. Army

Mr. Anthony Miranda – U.S. Department of State

Col Samuel Oppelaar III– U.S. Space Force

CAPT Herb Thompson – U.S. Navy

Faculty Advisors

Dr. Clark M. Groves,
Professor, The Eisenhower School, National Defense University

Col Laurel V. Walsh,
Assistant Professor & U.S. Space Force Chair to the National Defense University

Field Studies Hosts and In-Class Guest Speakers

In-Class Speakers

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- LeoLabs
- Satellite Industry Association (SIA)

Washington, D.C. Site Visits & Speakers

- White House
  - National Space Council (NSpC)
  - National Security Council (NSC)
  - Office Of Science and Technology Policy (OSTP)
  - Office of Management and Budget (OMB)
- U.S. Department of Defense (DOD)
  - Office of the Secretary of Defense for Space Policy
  - Office of the Assistant Secretary of the Air Force for Space Acquisition and Integration
  - Space Development Agency (SDA)
  - U.S. Space Force/S2
  - U.S. Space Force /S5/8
- National Geospatial-Intelligence Agency (NGA)
  - NGA Commercial Space Office
  - NGA GEOINT Operations Center (NGOC)
  - NGA GEOINT Functional Management (GFM)
  - NGA Research & Development
  - NGA Source
- National Reconnaissance Office (NRO) Commercial Space Office
- U.S. Department of Commerce (DOC), National Oceanic and Atmospheric Administration (NOAA), Office of Space Commerce
- National Aeronautics and Space Administration (NASA)
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  - Science and Technology Partnership Office
  - Space Operations Mission Directorate
  - Space Technology Mission Directorate
  - Commercialization, Innovation, and Synergies (CIS) Office
- U.S. Department of State (DOS)
  - Office of Space Policy, Bureau of Ocean and International Environmental and Scientific Affairs
  - Office of Emerging Security Challenges, Bureau of Arms Control and International Security
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- Iridium Satellite & Network Operations Center
  - Iridium
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- SpaceX
- U.S. Space Force (USSF)/Space Systems Command (SSC)
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  - Commercial Space Office (COMSO)
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- Colorado School of Mines
- Lockheed-Martin Space
- Space Information Sharing and Analysis Center (Space-ISAC)
- True Anomaly
- United Launch Alliance (ULA)
- Buckley Space Force Base
  - USSF/Space Base Delta 2
  - USSF/Space Delta 4
  - Aerospace Data Facility-Colorado (ADF-C)
- Peterson Space Force Base
  - U.S. Space Command (USSC)/J2
  - USSC/J8
  - USSC/Strategic Innovation Group (SIG)
  - USSF/Space Operations Command (SpOC)
  - Space Warfighting Analysis Center (SWAC)
- Schriever Space Force Base
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- Axelspace
- iSpace
- Japan Aerospace Exploration Agency (JAXA) & Tsukuba Space Center
- Japan Institute for Space and Security (JISS)
- Japan Ministry of Defense (MOD)
  - Space and Ocean Policy
  - Air Staff Operations (ASO) – A5, Space Systems Section
- Mitsubishi Electric Corporation (MELCO) Kamakura Works Factory
- Mitsubishi Heavy Industries (MHI) Tobishima Plant
- Japan National Space Policy Secretariat (NSPS)
- PD Aerospace, Ltd.
- Space BD
- SPACETIDE
- United States Embassy to Japan

Acronym List

AFRL	Air Force Research Laboratory
APS-R	Advanced Passive Refueling System
ASAT	Anti-Satellite
CLPS	Commercial Lunar Payload Services
CONFERS	Consortium for Execution of Rendezvous and Servicing Operations
CSCO	Commercial Satellite Communications Office
CSpO	Combined Space Operations
C2	Command and Control
DAF RCO	Department of the Air Force Rapid Capabilities Office
DARPA	Defense Advanced Research Projects Agency
DOC	United States Department of Commerce
DOD	United States Department of Defense
DOS	United States Department of State
DIU	Defense Innovation Unit
EAR	Export Administration Regulations
EBB	Exploit, Buy, Build
ELSA-d	End-of-Life Services Demonstration
FCC	Federal Communications Commission
GDP	Gross Domestic Product
GEO	Geosynchronous Earth Orbit
GPS	Global Positioning System
IARPA	Intelligence Advanced Research Project Activity
ISAM	In-Space Servicing, Assembly, and Manufacturing
ISO	International Organization for Standardization
ITAR	International Traffic in Arms Regulations
ITU-R	International Telecommunications Union-Radiocommunication
JAXA	Japan Aerospace Exploration Agency
JISS	Japan Institute for Space and Security
LEO	Low Earth Orbit
MDA	Missile Defense Agency
MELCO	Mitsubishi Electric Corporation
MEO	Medium Earth Orbit
MEV	Mission Extension Vehicle
MHI	Mitsubishi Heavy Industries
MILSATCOM	Military Satellite Communications
MOD	Ministry of Defense
NASA	National Aeronautics and Space Administration
NGA	National Geospatial-Intelligence Agency
NOAA	National Oceanic and Atmospheric Administration
NRL	Naval Research Laboratory
NRO	National Reconnaissance Office
NSA	National Security Agency

NSC	National Security Council
NSpC	National Space Council
NSPS	National Space Policy Secretariat (Japan)
NUDET	Nuclear Detonation Detection
OMB	Office of Management and Budget
OSAM	On-orbit Servicing, Assembly, and Manufacturing
OSTP	Office of Science and Technology Policy
PLA	People's Liberation Army (PRC)
PLEO	Proliferated Low Earth Orbit
PNT	Precision, Navigation, and Timing
PRC	People's Republic of China
PRM	Passive Refueling Module
RDT&E	Research, Development, Test, and Evaluation
RPO	Rendezvous and Proximity Operation
SAML	Space Access, Mobility, and Logistics
SATCOM	Satellite Communications
SDA	Space Domain Awareness
SIA	Satellite Industry Association
SML	Space Maintenance and Logistics
SpaceX	Spacecraft Exploration Technologies Corporation
SpRCO	Space Rapid Capabilities Office
SSC	Space Systems Command
SWAC	Space Warfighting Analysis Center
TacSRT	Tactical, Surveillance, Reconnaissance, and Tracking
TT&C	Telemetry, Tracking, and Commands
ULA	United Launch Alliance
USG	United States Government
USSC	U.S. Space Command
USSF	United States Space Force

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1. Introduction

The establishment of the United States Space Force (USSF) marks a significant shift in space operations for the United States, highlighting the strategic importance of space for both national security and economic growth. As the newest branch of the U.S. Armed Forces, the USSF is dedicated to protecting U.S. and allied interests in the increasingly contested and congested realms of outer space. The success of its mission depends upon its ability to foster a dynamic commercial space industry marked by economic vitality and technological innovation.

The commercial space industry is experiencing unprecedented growth driven by technological advancements and increased private sector investment. One of the most promising growth areas is In-Space Servicing, Assembly, and Manufacturing (ISAM). The ability to enhance the functionality and longevity of operational equipment routinely is a core military logistics capability. Applied to space operations, ISAM could revolutionize how the USSF builds, deploys, and maintains its space architecture. With its advanced technology requirements, the USSF is positioned to lead the development of a robust ISAM market. Synergistically, the mature capabilities beginning to emerge from the commercial ISAM market will be critical enablers of future space superiority missions vital to U.S. national security. The USSF must therefore strategically co-invest with commercial firms to develop a mature and robust ISAM market rapidly. It must also closely coordinate its ISAM efforts with allies, partners, and other U.S. government (USG) agencies. By supporting ISAM efforts, the USSF will enrich broader commercial capabilities that it can exploit for missions at lower costs, enhance relationships and resource pooling with allies and partners with shared vested interests in space, and foster further interagency cooperation to benefit American innovation and economic growth.

This report analyzes the strategic necessity of integrating emerging commercial ISAM products and services with USSF capabilities. To set the stage, the next section outlines the

strategic environment, including stakeholders' interests in the U.S. commercial space industry. As further background, Section 3 evaluates recently released U.S. military commercial space strategies and the proposed FY2025 USSF budget. Section 4 presents the report's core analysis on the importance of fostering the growth of new ISAM markets to enable the long-term success of commercial integration efforts and thereby ensure continued U.S. space superiority. Finally, Section 5 offers a series of policy recommendations to facilitate the findings of this report.

2. Strategic Environment

Before examining arguments on the need to facilitate the growth of mature ISAM markets to meet future USSF mission demands, it is useful to examine several elements of the strategic environment that inform U.S. national security in space.

2.1 Threats and Challenges

The People's Republic of China (PRC) and the Russian Federation view space as a warfighting domain. They seek to achieve technological, military, and economic dominance, while eroding the United States' leadership in outer space endeavors. Their aggressive approaches present clear threats and challenges to the very access and use of space that impacts the United States, its allies and partners, and their shared civil and commercial interests.[1] In April 2024, the PRC Central Military Commission announced the restructuring of their armed forces to establish an Aerospace Force and Information Support Force to improve efficiency and integration of space and information operations to influence how the new forces "potentially develop capabilities that may threaten adversaries space systems."[2]

A vivid recent example Russia's aggressive actions in space occurred on the eve of its invasion of Ukraine in 2022 when the Russian military conducted a cyber-attack on ViaSat's KA-SAT network, a dual-use service supporting commercial and military subscribers in Europe. Russia and the PRC have also heavily invested in advanced counter-space and anti-satellite

(ASAT) capabilities to disrupt, degrade, or destroy adversary space systems. These threat capabilities range from electronic warfare and cyber warfare systems to direct ascent ASAT missiles and directed energy systems to kinetic kill vehicles that can operate in orbit.[3]

Coupled with advances in counterspace weapons, Russia and the PRC have also made significant strides in securing assured access to space and resiliency in their space architectures. In particular, the PRC has exhibited exponential growth in space technologies and proliferation of assets in space, leading the Office of the Director of National Intelligence to assess that it will achieve "world class status" in space by 2030.[4] The Center for Security and Emerging Technology also concluded that the PRC has achieved multiple resiliency goals in space, including satellite proliferation in diverse orbital locations, greater access to space with a robust launch industry, and tactically responsive space launch.[5]

Furthering its resilience in space, the PRC officially recognized the need to develop ISAM capabilities, including satellite inspection, repair and refueling, in 2015 when it established the goal of achieving breakthroughs in on-orbit servicing technologies by 2030. Since 2018, the People's Liberation Army (PLA) has been actively incorporating lessons learned from computer simulations and past ISAM-related missions to enhance future logistics capabilities, including orbital maintenance and debris clean-up.[6] In 2021, the PRC also demonstrated its ability to conduct complex rendezvous and proximity operations (RPO) when a ShiJian-21 (SJ-21) satellite equipped with a robotic arm tracked and docked with a defunct satellite and then moved it to a GEO graveyard.[7]

ISAM capabilities, including satellite inspection and repair systems, are inherently dual use and adaptable for counterspace operations.[8] As the USSF seeks to maintain space superiority, it must account for the PRC's Military-Civil Fusion strategy, which mandates all of China's technological advancements, whether civil or commercial, be made available to the PLA.[9]

2.2 Stakeholder Interests

The integration of commercial space capabilities represents a pivotal strategy for the USSF. Applied carefully, it will enhance the USSF's operational capabilities and ensure continued superiority in space while mitigating threats from adversarial state actors. Key stakeholders in these efforts include various DOD and USSF agencies, the White House, commercial partners, Congress, and international allies and partners.[10] While there is general interest across USG stakeholders in developing ISAM, specific stakeholder interests vary. DOD and USSF efforts to date have been limited, while the White House and Congress have indicated stronger support. Moreover, commercial firms are actively developing new ISAM capabilities. International allies and partners such as Japan and the United Kingdom have achieved some success in fostering ISAM capabilities. Addressing such diverse stakeholder interests cohesively is vital for the USSF's effective integration of commercial ISAM capabilities.

2.2.1 Department of Defense and United States Space Force

As the DOD and USSF integrate commercial ISAM solutions into the U.S. military's new hybrid space architecture, they seek assurance that it will bolster mission readiness and operational capabilities without compromising strategic objectives. The USSF's Commercial Space Strategy underlines the necessity to "achieve integration prior to crisis," ensuring that commercial systems are seamlessly operational within military architectures when needed.[11] Additionally, security and resilience are paramount, to include both physical and cyber space threats. The DOD and USSF must adopt commercial ISAM systems that can withstand diverse threats, thereby enhancing the overall resilience of space operations.[12]

The USSF manages technical and business risks while evaluating the viability of commercial ISAM partnerships. While intrigued by the potential benefits of in-orbit refueling,

the Space Force is still unclear on the industry's business model and whether refueling would justify a larger financial commitment given recent emphasis on proliferated low earth orbit (PLEO) satellites.[13] Companies are pioneering techniques to refuel satellites in space, but the business model remains unproven at scale, leaving USSF reluctant to make large commitments.

2.2.2 The White House

Chaired by Vice President Harris, the National Space Council (NSpC) synchronizes the United States' civil, commercial, and national security space activities to ensure the continued growth and preeminence of a "robust and responsible U.S. space enterprise."[14] A key element of that effort is promoting the growth of new markets in the U.S. commercial space industry, including ISAM, to build and sustain the national economy. Notably, while USSF leadership has stated that it does not want to be an anchor customer for emerging commercial space firms, the NSpC and other civil space leaders have argued strongly for U.S. government support in developing new space markets that may benefit both the USSF and U.S. economic growth.[15] For example, executive branch leaders have pointed to examples of government support of efforts to foster competition. These new capabilities revolutionized the space economy and provided important benefits to U.S. military use of space, including SpaceX launch and resupply capabilities,[16] the NGA's early adoption of commercial satellite imaging services,[17] and NASA's Commercial Lunar Payload Services (CLPS) program.[18] This apparent contradiction between USSF and NSpC leadership sends confusing signals to the commercial ISAM industry and its investors, unnecessarily inhibiting innovation and growth of this strategic market.

2.2.3 Commercial Partners

Potential profit and market efficiencies drive the commercial sector, and these incentives align with the USSF's need for cost-effective and innovative solutions. These firms seek clarity in partnership opportunities and regulatory frameworks to align their products and services with

military needs, securing a steady demand for their services and supporting economic growth through job creation and technological advancements. Commercial space firms thrive on competitive innovation and the reduction of barriers to entry. Participant growth in the commercial ISAM market will offer significant economic benefits by reducing costs and increasing innovation. Working closely with the DOD and USSF will elevate a company's reputation and profile within the industry and often attracts private sector investment.

2.2.4 Congress

Congressional interests include oversight, accountability, and the strategic use of funds. Congress aims to ensure that USG investments in commercial ISAM enhance national security and provide taxpayer value, thus influencing the scope and scale of commercial integration efforts. Further highlighting the contradiction between USSF and NSpC leadership over the role of government in fostering the growth of new commercial space capabilities, Senate Armed Service Committee and House Appropriations Committee members recently pressed USSF leadership on why the Space Force was proposing to spend only $20 million to explore space access, mobility, and logistics when the PRC has already demonstrated such capabilities.[19]

2.2.5 Allies and Partners

Allies look for assurance their engagement with the USG directly, and via commercial activities, enhances mutual security interests and respects sovereign operations. U.S. alliances are crucial for developing a unified approach to space operations, enhancing global monitoring capabilities, and ensuring the collective defense of critical space infrastructure. The USSF is enhancing its existing alliances through the Combined Space Operations (CSpO) initiative, which recently added Italy, Japan, and Norway.[20] By shoring up global space security and resilience, this multinational approach bolsters the United States efforts against competitors like the PRC and Russia and permits collaboration and shared resources among likeminded nations.[21]

3. Analytical Framework and USSF Budget

Before examining how to leverage ISAM markets in Section 4, it's useful to examine the broader context of commercial space initiatives, and establish a framework for analyzing them.

3.1 Call to Commercialization

The U.S. government recognizes the value of partnering with commercial firms to leverage space-based capabilities. Every major USG space acquisition organization has a commercial space office that supports intelligence, military, and civil space operations. The White House also emphasizes the importance of commercial space markets, which influences efforts throughout the government. Notably, the DOD recently published a Commercial Space Integration Strategy, and the USSF published a Commercial Space Strategy, reinforcing the need to integrate commercial space solutions into the U.S. national security space architecture. Both strategies directly address commercial ISAM capabilities.[22]

All government agencies pursuing commercial space strategies face a host of practical challenges. One challenge is developing a framework to decide when to select a commercial solution, rather than a traditional government acquisition. Another challenge is understanding how to incentivize commercial firms to support national defense requirements, especially those operating in emerging markets like ISAM. It is vital for DOD to send clear market signals to industry to private-sector investment. This lays the foundation for commercial space companies to create products and services that align with national security needs and reduce costs for the DOD. This report introduces one such framework below.

3.2 Exploit, Buy, Build: A Commercialization Framework

The design of the defense acquisition system reflects the context of the 1990s Cold War end and sweeping drawdown of the defense industry.[23] The system emphasizes compliance with

product performance and resource constraints, areas that also align with two of the most compelling forces facing the commercial space industry: product differentiation and cost control. However, dramatically different perceptions about the value of time create significant barriers between the DOD and commercial firms. This is especially true for start-up firms.

Two time-related barriers have further impeded closer partnerships between the USSF and commercial firms. First is the time required to meet complex government technology and integration requirements. Second is the time required to learn government budget and finance processes. For a start-up firm, these barriers create an existential dilemma -- how to pay ongoing bills, while scaling revenues to close a business case in time to meet the limited patience of investors. In recent years, certain key industry-wide trends have helped lower barriers to entry for small firms, including a dramatic decrease in launch costs, largely driven by SpaceX. This trend has piqued venture capital interest in funding start-ups pursuing commercial space business plans, but venture capital interests are fickle. The USSF's window to maximize the opportunity to leverage and integrate commercial capabilities as early adopters may be limited.

To best leverage commercial space capabilities, the USSF must have a framework for deciding when to pursue a commercial market solution. In 2021, General Michael Guetlein introduced a broad concept to assess the feasibility of a commercial solution to fulfill a military mission. His Exploit, Buy, Build (EBB) strategy prioritizes the exploitation of already fielded space systems to meet mission needs. The next objective is to buy "existing technology and available commercial solutions" whenever possible. The last option is to develop and build systems internally "only when necessary."[24]

To illustrate trade-offs among acquisition options, a framework in Table 1 qualitatively assesses the impact of choosing between Exploit, Buy, Build options on six key factors.

Impact On	EXPLOIT Fielded DoD Systems	BUY Commercial Solutions	BUILD New DoD Systems
Cost	Low	Moderate	High
Schedule	Low	Moderate-High	High
Performance	Low-Moderate	Moderate	High
Non-Commercial Requirements	N/A	Low	High
Rapid Fielding Risk	N/A	Low-Moderate	High
Wartime Resilience	Moderate	Low-Moderate	High

*Red denotes traditional programmatic assessment metrics

Table 1. Exploit, Buy, Build Commercialization Framework. A framework to qualitatively assess the impact of choosing between "Exploit, Buy, Build" acquisition options, using six traditional and commercial programmatic assessment metrics.

Cost: Total estimated cost to field/fulfill a capability.
Schedule: Estimated time it will take to field a capability.
Performance: Ability of a solution to meet a set of specified requirements.
Non-Commercial Requirements: Extent to which govt-unique specs are required.
Rapid Fielding Risk: Schedule risk resulting from the volatility of a given acquisition approach (*e.g.*, funding stability, delays from Continuing Resolutions, etc.).
Wartime Resilience: Ability to meet mission requirements across spectrum of conflict.

This framework could assist senior defense leaders in assessing the viability of the three acquisition options based on mission area by illustrating their individual strengths according to both government and industry benefit. One of the government's primary considerations when assessing each acquisition approach (aside from mission capability) should be the level of positive externalities resulting from its investments. For example, experts note when considering investments in capabilities like ISAM with significant potential spillover effects (*e.g.*, satellite life extension, debris mitigation, and maneuver), government investment can provide positive externalities beneficial to both the DOD and industry. This alignment of interests further supports a more cohesive partnership between the USSF and commercial firms on ISAM.[25]

An analysis of the National Security Space Launch program demonstrates how this framework can be applied to acquisition strategy determinations. In 2015, the DOD focused on "building" launch capabilities, and United Launch Alliance (ULA) was the only company certified to launch national security satellites. DOD requirements drove ULA to maintain an exquisite launch capability that could deliver satellites weighing tens of thousands of pounds over thirty thousand kilometers into space. These requirements far exceeded commercial demand, which meant the DOD was responsible for closing ULA's business case. The emergence of the private launch company SpaceX, supported in part by NASA funding, introduced commercial competition and allowed the government to shift from "build" to "buy."[26] This competition has not only given the DOD two launch capable providers, but it has also significantly contributed to lower launch costs through commercial procurement. For example, while the DOD budgeted $1.4 billion to procure only three launch services in 2015, USSF has procured fifteen launch services for only $3 billion in 2024.[27] In this case, the government traded non-critical performance requirements by leveraging SpaceX's reusable launch service to gain significant savings in cost and schedule. USSF must identify and invest in the next set of key technologies whose development will yield downstream benefits like the growth in space access that followed the introduction of reusable rockets. The capability and technologies required to execute ISAM will usher in the next wave of commercial investment, development, and future partnership opportunities for the Space Force.

3.3 Proposed FY2025 U.S. Space Force Budget Review

The USSF's proposed FY2025 budget request is $29.4 billion, which is two percent ($0.6 billion) less than its FY2024 request. The budget is distributed across the thirteen national security space areas to meet the service's three guiding principles: "(1) avoid operational surprise in the space domain; (2) deter attacks against U.S. interests in space; and (3) prevent an

adversary from using space to attack our homeland or the Joint Force."[28] As Table 2 demonstrates, priority funding areas include satellite communications (SATCOM), missile defense, Space Domain Awareness (SDA), and space vehicle launch services.

While a comprehensive analysis of the proposed FY2025 USSF budget is beyond the scope of this report, it is important to highlight proposed ISAM-related funding, which is included within the Space Access, Maintenance, and Logistics (SAML) category in Table 2. Of the $2.26 billion requested for SAML, $20 million is designated for RDT&E in the Space Maintenance and Logistics (SML) program, which includes the ISAM capabilities discussed in this report.[29] Notably, the proposed FY2025 budget does not include SML funds programmed beyond FY2025. While the funding and designation of the SML program to synchronize commercial integration represents a critical step forward, balancing this funding to a level similar to commercial integration efforts with SATCOM ($246.1 million and an additional $1.2 billion towards a commercial working capital fund requested) and certain areas of SDA ($115 million requested)[30] will send a stronger demand signal for commercial firms developing the ISAM capabilities necessary for the USSF's long-term mission success.

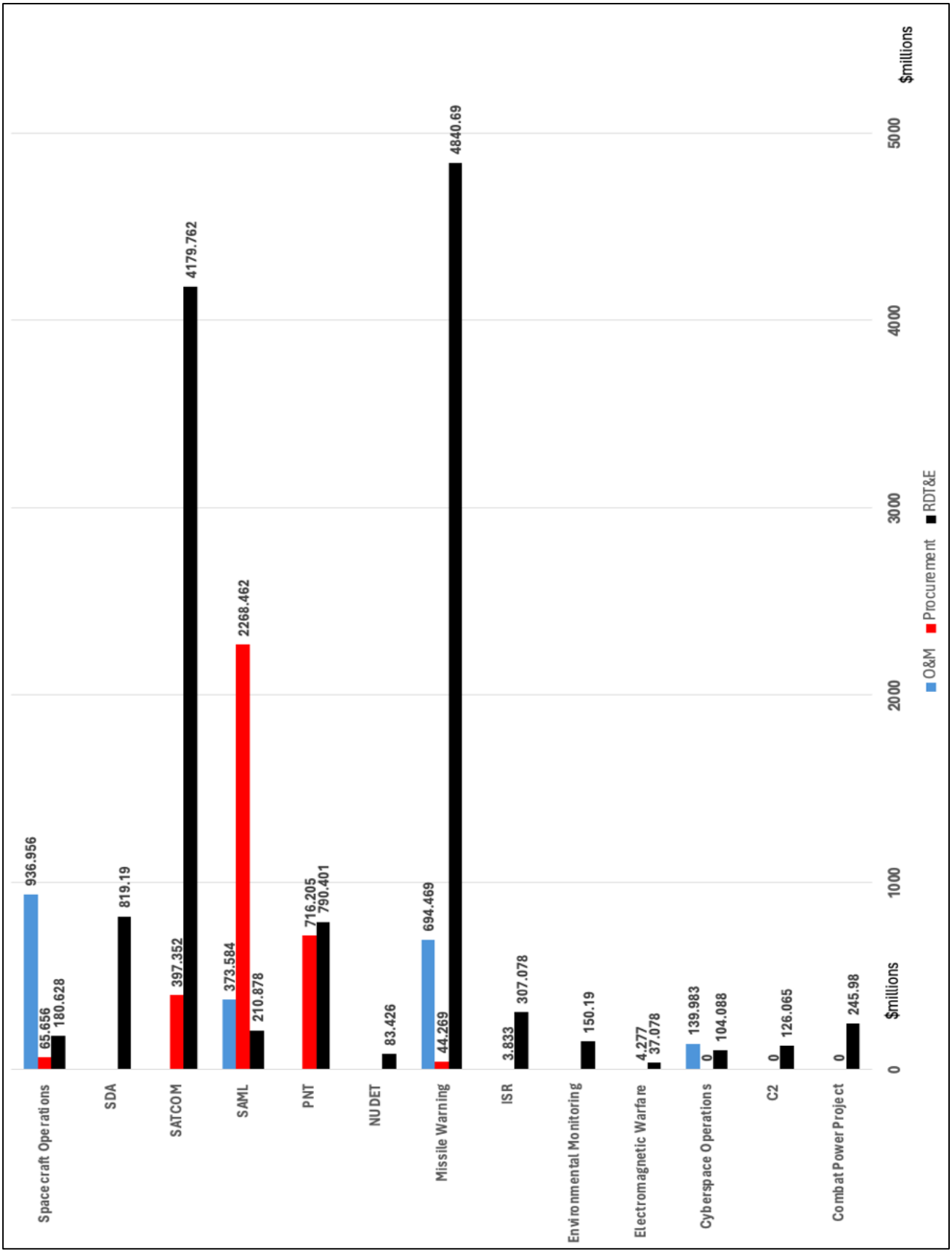


Table 2. Alignment of USSF Resources to Space National Security Missions. USSF's proposed FY2025 budget allocations for the thirteen national security space areas.

4. The Strategic Importance of In-Space Servicing, Assembly, and Maintenance (ISAM)

4.1 The Emergence of a New Market

Innovative firms are creating a new market in the commercial space sector to provide ISAM services such as in-space refueling, satellite maintenance, and orbital transfer. The emergence of the ISAM market has long-term implications for U.S. space superiority. USSF should dedicate additional resources to the development of this market. By doing so, the USSF can address both current and future challenges in space operations, enhance its strategic posture, and improve operational capabilities in space. Profitable domestic commercial ISAM markets will enable the USSF to access key capabilities at lower costs. Bolstering nascent commercial firms developing new ISAM technologies will also incentivize firms and their investors to consider developing new products and services in each of the USSF's mission areas, giving the USSF additional commercial options. In addition, early investment can enhance relationships and resource pooling among U.S. allies and partners with shared vested interests in space, while expanding opportunities in space that can stimulate American innovation and long-term economic growth. This section analyzes the commercial ISAM market in the United States and its potential impact on U.S. national security interests.

4.2 What is Driving the ISAM Market?

A growing number of companies are developing ISAM service capabilities. As in other space sectors, recently lowered launch costs have incentivized firms to seek first-mover advantage in emerging markets. Firms are developing and testing the ability to move space assets, to provide key capabilities needed by both commercial and national security customers.

Technologies such as autonomous operations, efficient propulsion systems, RPO, and space docking are maturing sufficiently to unlock new ISAM applications. One of the most

notable of these applications is debris removal. The number of measurable objects in orbit is increasing exponentially, forcing satellite operators to monitor orbits constantly to prevent collisions.[31] Resolving these potential convergences requires a satellite to burn precious fuel, which leaves less energy available for basic operations and station-keeping maneuvers. Less fuel also means limited options for reacting to celestial or state-sponsored threats. Propulsion ISAM systems can facilitate the reduction of debris within congested orbits.

Another key driver behind the demand for ISAM is the renewed global interest in the cislunar region and returning to the moon's surface. Today, commercial entities and governments are tapping into cislunar and lunar operations to explore deep space, seek future development, and pursue economic benefits from mining and harvesting natural resources. Propulsion ISAM systems are key enablers for the complex infrastructure required to pursue these ventures. ISAM could also greatly aid launch capabilities to depart the moon's surface and return to Earth by allowing transporters to carry greater payload instead of substantial fuel stores.

In addition, concerns over global launch capacity have fueled interest in ISAM capabilities to support orbit insertion and relieve the demand for launch services. Global launch attempts rose almost twenty percent from 186 in 2022 to 223 attempts in 2023.[32] While the number of launches is up, demand continues to outpace launch supply due to increased satellite manufacturing. One important reason for this is that only two heavy lift options are currently in operation, ULA's Atlas V rocket and SpaceX's Falcon Heavy.[33]

Commercialization has shifted the paradigm for how ISAM products and services enter the market. Previously, large defense prime contractors typically built spacecraft capable of performing ISAM missions, which the U.S. government would buy and operate. In today's market, venture capital-backed startup companies are instead developing novel ISAM solutions and offering them as a service. This approach will continue to fuel competition as the market

matures. It also provides the U.S. Space Force a more fiscally responsible approach to acquire ISAM services amid its projected growth in space missions.

The ISAM market is bustling with competition and investment. Venture capital funding and corporate resources are plentiful. Government research and development are also supporting many programs, albeit with low-dollar investments. Northrop Grumman, Lockheed Martin, and Boeing are all considering ISAM applications within their space product lines, with some products already tested on orbit. Traditional defense prime contractors are not alone. Startup companies are also making substantial progress in fieldable capabilities, as substantial venture capital-backed investment and technological advances have helped startups overcome traditional barriers to entry. Seizing the advantage of a national first adopter in this competition is critical for continued U.S. dominance in space and has profound national security implications.

4.3 The Importance of ISAM Refueling Services

The ability to provide ISAM refueling services to satellites serving critical roles in U.S. national defense will strategically enhance U.S. superiority in space. ISAM refueling crosscuts several key space operational capabilities, including SDA, TacSRT, SAML, spacecraft operations, orbital warfare, and C2.[34] Most satellites, including over 87% of U.S. military satellites, have far exceeded their estimated design life.[35] Often, the fuel source runs out before the technology on the satellite stops working. ISAM refueling services would allow the USSF to mitigate the risk of potential gaps in critical capabilities by keeping those systems functioning. Refueling services would also reduce the need for replacements and launch, which potentially saves costs, mitigates space debris, and provides time for development of next-generation capabilities.[36] U.S. Naval Fleet Admiral Chester W. Nimitz highlighted the strategic impact of refueling at sea, saying, “Refueling at sea was the Navy’s secret weapon of World War II, the key to our operations in the vast Pacific Ocean.”[37] The U.S. Navy’s ability to refuel at sea ensured it

maintained continuous operations across great distances, providing unparalleled, persistent, and resilient operations at sea. Similarly, today's emerging ISAM technologies for refueling in space could enable the USSF to sustain longer missions and achieve dynamic movement and maneuver, creating strategic advantages parallel to those experienced in the maritime domain.

The strategic implications of USSF's shift toward dynamic space operations underpinned by ISAM refueling capabilities are profound. If realized, this shift will enhance the USSF's ability to project power in space, protect critical space assets, and maintain global surveillance and communication networks in any orbit. Central to this operational evolution is the USSF's commitment to effectively performing dynamic movement and maneuver, marking a departure from the traditional, static orbital posture of space assets.[38] In-space refueling can significantly enhance the readiness and resilience of space assets, especially in times of crisis or conflict where space systems might be targeted. ISAM refueling capabilities provide flexibility to adjust in orbit or function without the need to deploy new satellites, enhancing the responsiveness and adaptability of space operations. Understanding the contested nature of the space domain and the limitations of conventional positional space operations, where satellites are deployed into orbit with minimal maneuverability, USSF has articulated a vision that underscores the imperative for sustained maneuver in space operations.[39] A significant cornerstone of this vision is the successful integration of commercial ISAM refueling and other capabilities.[40]

4.4 Commercial Refueling: A Near-Term Reality

USSF cannot currently conduct in-space refueling, severely restricting satellite life span, adaptability, maneuverability, and survivability. To fill this gap, USSF must explore purchasing services or acquiring new capabilities still in development. Northrop Grumman's Mission Extension Vehicle (MEV) is a new in-space servicing and refueling capability designed to extend the operational life of geostationary satellites by providing propulsion and attitude control once a

satellite's own resources are depleted. [41] The first MEV, MEV-1, successfully docked with an Intelsat satellite in 2020, demonstrating the practical application of this technology.[42] For the USSF, technologies like the MEV offers strategic value by providing a cost-effective solution to extend the life of critical space assets, ensuring sustained intelligence gathering and secure communications, and providing the U.S. with a critical operational advantage.

Other commercial firms are developing ISAM refueling capabilities that offer similar advantages. For example, Astroscale, a company specializing in on-orbit servicing and debris removal, is testing its own advanced docking and refueling technologies. In January 2024, Astroscale's End-of-Life Services demonstration (ELSA-d) showcased the ability not only to rendezvous and dock with defunct satellites, representing a leap forward in space debris management, but also to approach and dock safely with a satellite to refuel or provide external propulsion.[43] This capability demonstrates the feasibility of docking with non-cooperative, unprepared satellites, expanding the scope of in-space servicing. While ELSA-d focused on debris removal, Astroscale's docking technology can be adapted for refueling missions. By developing standardized docking plates and refueling interfaces, Astroscale offers a simple solution to help enable USSF dynamic maneuvers.

Northrop Grumman is also developing the Advanced Passive Refueling System (APS-R) under a USSF contract, enhancing autonomous docking and refueling in space. This system is a critical component of Northrop Grumman's Passive Refueling Module (PRM) designed to simplify and standardize in-space refueling processes with various spacecraft, offering flexibility for dynamic in-space operations and sustaining space missions.[44] Additionally, NASA's OSAM-1 (On-orbit Servicing, Assembly, and Manufacturing) project, intended to demonstrate advanced servicing capabilities including autonomous robotic refueling, highlighted the potential of space logistics. Although discontinued, the project's technological advancements laid the groundwork

for future servicing missions, demonstrating the strategic importance of autonomous docking and refueling systems in space exploration and national defense.[45]

5. Recommendations

To capitalize on ISAM's strategic advantages, USSF should establish a resourcing strategy to incentivize growth in the commercial ISAM refueling market, in line with short and long-term space operations and sustainment goals. This includes determining budget allocations, potential cost-sharing mechanisms, and exploring grant and incentive programs to stimulate research and development. Summarized in Table 3, this section highlights recommendations the USSF should pursue to best leverage opportunities in the emerging commercial ISAM market.

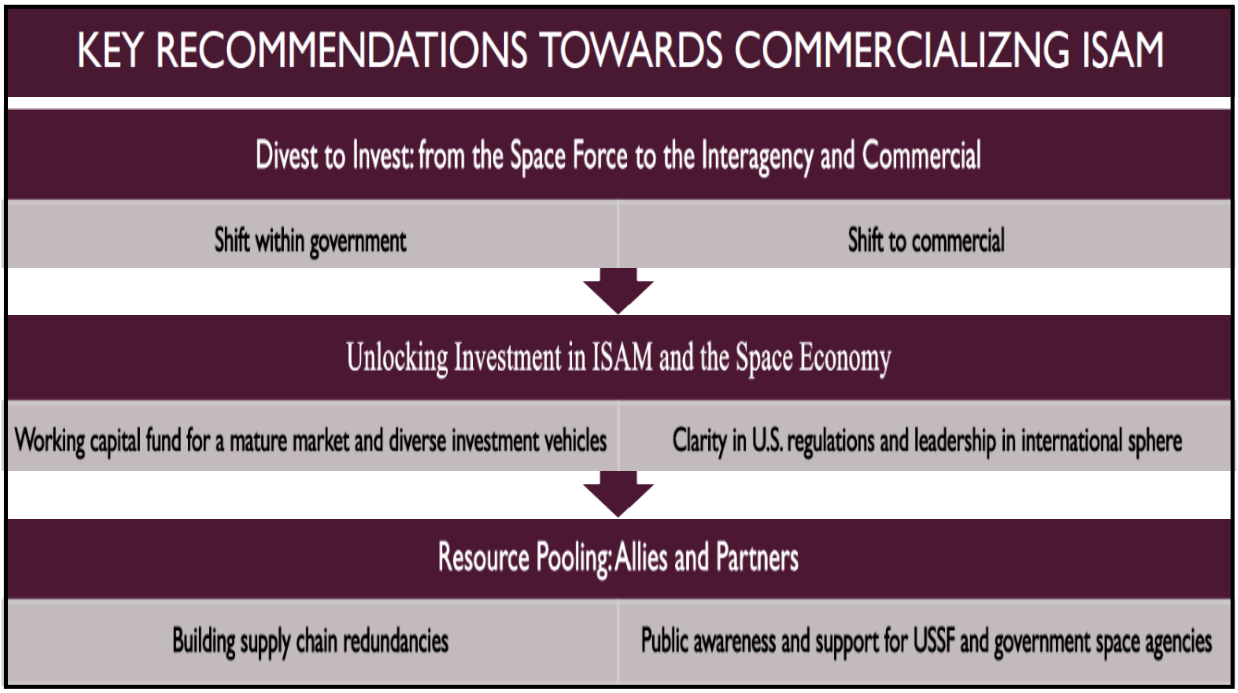


Table 3. Key Recommendations Towards Commercializing ISAM. Summary of this report's primary recommendations for the USSF to stimulate the growth of the commercial ISAM market.

5.1 "Divest to Invest": Expanding Commercial ISAM Capabilities

The DOD has tasked the USSF to integrate commercial capabilities to enhance U.S. military operations in, from, and to the space domain. As discussed above, the DOD and the USSF have both recently released commercial space strategies, but neither document describes

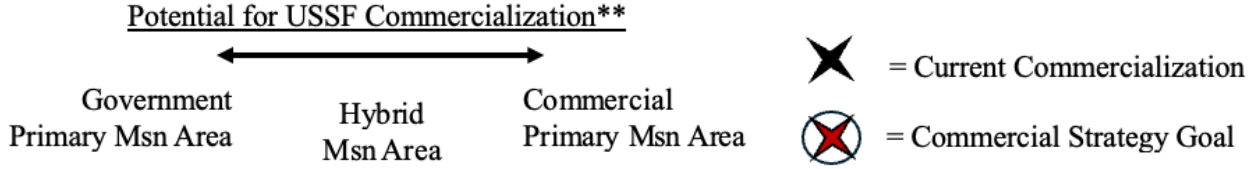
the current state of commercial integration nor how to reach its stated goals. To address these lacunae, Table 4 below depicts the current state of commercialization delineated by USSF mission areas and spacepower disciplines, overlaying them with the main missions of the USSF. It also shows recommended investment adjustments to main mission areas to realize direct cost savings. Transitioning more capabilities to commercial firms will ensure the USSF can focus on its critical national security missions while optimizing its resources to provide the best independent options for national security decision makers.

The columns in Table 4 group the three main USSF missions as outlined in the *Space Capstone Publication*: to preserve freedom of action in the space domain; to enable joint force lethality and effectiveness; and to provide independent options to national decision makers. A legacy mission originally assigned to DOD space capabilities, the first mission is to ensure the U.S. military can operate in space by understanding the domain and to ensure the U.S. has access to it at the times and places of its choosing. The second mission, also a legacy mission, is a force multiplier for the joint force through electromagnetic warfare, global positioning and timing, satellite communications, and tactical and strategic mission warning. The third mission, new with the standup of the Space Force as an independent service within the joint force, is to gain and maintain space superiority through offensive and defensive spacecraft operations, combat power projection, orbital warfare, cyber operations, and space battle management.[46]

Each cell in Table 4 lists a current USSF mission area. A black "X" shows the current commercialization level based on research, unit visits, and subject matter expert inputs. A circled red "X" shows this report's recommended level of commercialization.[47] To realize the cost savings associated with the commercialization goals outlined in the DOD and USSF commercial strategies, USSF should aim to meet the red X goals. This ensures the availability of the resources needed effectively meet the long-term requirements of the primary missions areas.

USSF Mission Areas/Spacepower Disciplines*		
Preserve Freedom of Action	**Enable Joint Lethality/Effectiveness**	**Provide Independent Options**
Space Domain Awareness (SDA) / *Non-Earth Imaging (NEI)*	Space Electromagnetic Warfare (SEW)	Spacecraft Operations
Intelligence, Surveillance & Reconnaissance (ISR) / Tactical Surveillance, Reconnaissance & Tracking (TacSRT)	*Position, Navigation & Timing (PNT)* / Navigation Warfare (NAVWAR)	Combat Power Projection / Orbital Warfare (OW)
Environmental Monitoring (EM)	Missile Warning (MW)	Cyber Operations
Space Access Mobility & Logistics (SAML) / In-Space Servicing, Assembly & Manufacturing (ISAM)	Satellite Communication (SATCOM)	Command & Control (C2) / Space Battle Management (SBM)
Data Exploitation and Enhanced Processing (DEEP)	Nuclear Detection (NUDET)	

*JP 3-14 & Space Capstone Publication & USSF Commercial Space Strategy.
USSF Divest some or all of the mission to other Gov't organizations.
Red text is emerging missions within the USSF Joint Commercial Operations cell.



**DoD Commercial Space Integration Strategy, categories

Table 4. Commercial Integration Strategy Linked to USSF Mission Areas / Spacepower Disciplines. USSF mission areas for application of "divest to invest" to ensure the service has the capabilities to provide independent options for national security decision makers.

As Table 4 demonstrates, this report recommends the USSF divest from multiple mission sets in the first and second discipline areas so that it can reinvest resources in the newest third discipline, which is critical to ensuring the USSF is combat ready to gain and maintain space superiority when tasked. To maximize the strategic impact of this resource reallocation, the USSF should prioritize transitioning ISAM, here included as part of SAML, to a primarily commercial mission area. This mission area has the most direct impact on the USSF's new primary mission of providing independent options to the joint force and best positions the USSF to achieve the strategic advantages highlighted in Section 4. To succeed in this transition, the USSF must proactively invest in the emerging ISAM market, advocate for regulatory reform, and seek opportunities to pool resources with allies and partners.

5.2 Unlocking Investment in ISAM and the Broader Space Economy

5.2.1 Seeding the Market

Multiple engagements with space startup companies, established defense contractors, and venture capitalists in recent months reveals that commercial space firms and their investors are seeking a clear signal of potential government revenues to continue to invest in developing new ISAM technologies. In particular, several startup firms noted the importance of clear U.S. government intention to fund new ISAM technologies for their venture capital fundraising efforts. To attract investment in emerging commercial space services, it is vital to provide investors with clear signals of future demand. The USSF should consider implementing demand forecasting initiatives to project future needs for ISAM services. These forecasts help investors assess market potential and justify allocating funds to developing innovative technologies. By demonstrating a robust demand outlook and USSF commitment to the ISAM market, these initiatives would reassure investors of the viability and profitability of their investments.

5.2.2 Space Investment Fund

Space startup firms highlight the value of early government revenues in overcoming barriers to market entry, beyond initial venture capital funding, into sustained operations and revenue generation. To further catalyze the development of ISAM markets, USSF should consider creating a Space Investment Fund. This fund would target startups and innovative projects that enhance on-orbit capabilities, including refueling and other maintenance services. These capabilities are critical for extending space assets' functionality and operational lifespan, ensuring space missions' long-term sustainability and effectiveness. The fund would provide crucial capital to ventures at the forefront of space technology, fostering a pipeline of innovations that could transform space logistics and infrastructure. Mirroring recent NRO efforts in the hyperspectral imaging market, the USSF can demonstrate its commitment to commercial ISAM by competitively selecting investments based on their potential to align with national security interests and their ability to contribute to robust U.S. space capabilities. In addition, as this market matures, USSF should consider the establishment of a working capital fund to support the purchase of in-orbit services, thereby providing mission flexibility throughout the interagency, while also demonstrating long-term commitment to commercial firms.

5.2.3 Matching Grants

To further stimulate innovation in the ISAM sector, USSF should consider introducing matching grants to incentivize private sector investment in ISAM technologies, offering dollar-for-dollar matching of private funds up to a predefined limit. This financial mechanism reduces the risk associated with high-cost, high-risk, but potentially high-reward ISAM projects. By mitigating some financial hurdles, these grants would encourage companies to invest in new technologies that are essential to sustain long-duration space missions and the rapid adaptation and upgrade of space systems in response to evolving technological and strategic landscapes.

5.2.4 Public-Private Partnerships

Public-private partnerships should also be a cornerstone of the USSF's strategy to integrate commercial sector innovation within its operational framework. By forging partnerships with firms specializing in ISAM, the USSF can co-develop mutually beneficial technologies. These collaborations allow for the sharing of risks and rewards associated with the research, development, and deployment of new space technologies. Leveraging USSF assets and capabilities, such as access to test facilities and regulatory support, can significantly lower private companies' entry barriers and operational costs. In return, the USSF gains access to innovative commercial technologies and agile business practices that it can integrate into broader national security missions. These partnerships both accelerate technological advancements and ensure that such developments are coordinated with the strategic objectives of USSF, enhancing overall space operation efficiencies and capabilities.

5.3 Regulations, Legal Frameworks, and Standards

Beyond reallocating USSF resources, seeding the ISAM market, and pursuing new investment strategies, the USSF should leverage its position in the broader space industry to advocate strongly for both domestic ISAM regulatory reform and the international adoption of ISAM-related legal frameworks and standards.

5.3.1 Current U.S. ISAM Regulations

The Federal Communications Commission (FCC) Space Bureau is the primary entity that licenses and regulates commercial spectrum management in the United States. Its efforts are key to ensuring the stable spectrum and bandwidth allocation needed for the safety and sustainability of ISAM missions.[48] The FCC already regulates radio frequency spectrums necessary for ISAM telemetry, tracking, and commands (TT&C), and in March 2024 it published a Notification of Proposed Rulemaking to propose a new framework for licensing space stations engaged in

ISAM.[49] This proposal is a crucial step toward establishing domestic standards and norms of behavior, ensuring effective and safe operation of ISAM activities, but more should be done.

5.3.2 Recommendations for Domestic Regulatory Reform

In collaboration with the FCC and other interagency partners, the USSF should pursue multiple lines of effort to foster the growth of the ISAM market through regulatory reform. For example, the USSF should advocate strongly for streamlined licensing processes that govern ISAM activities, an essential improvement to facilitate rapid innovation and deployment of new technologies. Navigating the U.S. regulatory environment is cumbersome due to the involvement of multiple agencies and the variety of requirements. To encourage more firms to enter the ISAM market, the USSF should advocate for a simplified, more transparent licensing framework from launch to de-orbit. This approach should involve consolidating ISAM approval processes under a single regulatory umbrella. By reducing bureaucratic hurdles and shortening the time frame for obtaining necessary licenses, the U.S. government would lower the entry barriers for new ventures and accelerate ISAM innovation, directly contributing to advanced capabilities and space resilience. As part of the licensing process, the USSF should also advocate that all new satellites that meet predetermined size, weight, and power requirements include both a standard refueling port and docking mechanism, both low-cost requirements that will further stimulate the growth of the commercial ISAM market.

The USSF should also actively support the development of regulatory sandboxes where new technologies can be tested and refined to foster innovation in ISAM. One way it can do so is by encouraging firms to utilize the FCC's Experimental License, which authorizes experimental missions for product development and market trials.[50] In addition, regulatory sandboxes provide a controlled environment where companies can experiment with new ISAM technologies without the typical constraints of broader regulatory frameworks. This approach allows for real-world

testing and rapid iteration of technologies like autonomous robotic repair systems, advanced materials suitable for space manufacturing, and novel spacecraft assembly techniques. The USSF could establish these sandboxes in hosted space areas or ground-based facilities that simulate the space environment, ensuring access to newer, smaller firms that often lack familiarity with the regulatory process. By providing a space where regulatory flexibility is coupled with robust oversight, the USSF would speed up technological development and deployment cycles while ensuring that these innovations adhere to safety and operational standards that are necessary once they are fully integrated into commercial and military space operations.

5.3.3 Advancing International Legal Frameworks and Standards

Implementing new U.S. domestic regulations risks pushing companies towards business opportunities in other space-faring nations with less stringent regulations. To mitigate that risk, the U.S. government, supported by the USSF, should strongly advocate for legal frameworks and standards consistent with U.S. best practices. The rapidly evolving nature of commercial ISAM activities necessitates significant updates in international space law. Current treaties like the 1967 Outer Space Treaty were drafted at a time when private industry rarely participated in space. As commercial firms now play a crucial role in the space economy, there is a pressing need to revise these legal frameworks to address new challenges and opportunities.

Coordinating closely with the National Space Council, the USSF should proactively encourage its interagency partners involved in international governance, treaties, and standards development towards enhanced regulation of commercial ISAM activities. Clear legal guidance will demonstrate the USG's commitment to ISAM growth by ensuring that legal protections are in place to encourage business development. U.S. international leadership, backed by domestic interagency standards and regulation, will also facilitate cooperation and conflict resolution in an increasingly crowded space environment.

Moreover, establishing clear property rights, equipment standards, and liability regimes in space will encourage responsible behaviors and sustainable practices among space-faring entities, thereby enhancing the overall governance of space activities. Encouraging interoperability, facilitated by consistent regulations, expands international markets to industry and enables emerging space-faring nations to purchase ISAM services to meet their needs. While the PRC and Russia may prevent the adoption of broad international standards, concurrence among allies and partners remains vital in building norms and demonstrating that countries like the United States are ideal for space business innovation. This legal clarity is essential not only for the growth of the commercial ISAM market but also for maintaining international peace and security in space, making it a critical area of focus for the USSF's legal advocacy.

As ISAM activities increase, so does the complexity of space traffic management. While not solely a USSF responsibility, USSF can play a significant role in developing and normalizing ISAM best practices to ensure they contribute positively to space sustainability. These standards should focus on minimizing space debris, a growing concern with potentially catastrophic consequences for both space operations and broader international relations, and monitoring space traffic. Preventing accidental damage will highlight negligent or adversarial action more quickly, allowing for a comprehensive international response. By working with the Department of Commerce and other interagency partners, the USSF can safeguard the interests of the United States, while contributing to global efforts to make space a safe and sustainable environment for all users. Implementing robust internationally recognized space traffic management measures will enhance ISAM operational safety and ensure its long-term sustainability.

The USSF should also coordinate with USG interagency partners to advance broader adoption of ISAM international standards that will help nurture a more stable, predictable, and mature operating environment. For example, the USSF should support the FCC's work with the

United Nation's International Telecommunications Union Radiocommunications Sector (ITU-R), which is working to update to the Radio Regulations Treaty to incorporate technical and regulatory measures for inter-satellite services, an important step in shaping international ISAM regulations and standards.[51] Similarly, the USSF should coordinate with the Consortium for Execution of Rendezvous and Servicing Operations (CONFERS), a non-profit organization created by DARPA. CONFERS is advocating with the International Organization for Standardization (ISO) to create standards and norms of behavior for RPO and on-orbit servicing for both commercial and government missions.[52] The ISO published these standards in July 2022, but they are awaiting the ISO Central Secretariat's final confirmation, after which they will be published as an International Standard. CONFERS is also developing recommendations for on-orbit cryogenic refueling standards, which are expected by the end of 2024. Efforts such as these promise to enhance safety and efficiency in space operations through harmonized best practices and protocols, thereby enhancing the resiliency of the ISAM market, something the USSF should continue to support.[53]

5.4 Pooling Resources with Allies, Partners, and Commercial Firms

As the growing roster of Artemis Accords members demonstrates, countries have a mutual interest in collaborating with the United States in space. Given restraints on its budget, the USSF should seek to partner more closely with allies and partners on areas of mutual interest, particularly space traffic management and space sustainment, to foster the development of commercial ISAM capabilities.

International collaboration in ISAM offers significant innovation and cost-efficiency benefits but poses national security risks. These risks include unintended technology transfers, especially concerning dual-use technologies that adversaries could exploit for military purposes, and the exposure of sensitive information due to partners' potential intellectual property

vulnerabilities. Additionally, reliance on specific commercial or international entities introduces risks associated with their stability and reliability. Mitigating these risks requires robust technology control regimes with strict guidelines on technology sharing, including legal tools like the International Traffic in Arms Regulations (ITAR) and Export Administration Regulations (EAR). Enhancing security protocols for intellectual property management via non-disclosure agreements and secure communications is also essential. Despite these risks, the on-going success of the hosted payload program between Japan's Quasi-Zenith Satellite System (QZSS) PNT satellite constellation and the USSF demonstrates that careful collaboration with allies and partners can deliver significant value to both sides.[54]

Diversification of commercial partnerships and redundancy in supply chains also mitigates undue pressure on single sources, while standardizing security practices ensures all partners meet USSF security requirements. Continuous monitoring and regular risk assessments are vital to adjust strategies promptly. A critical aspect of these strategies is balancing the need to restrict access to sensitive technologies while ensuring the commercial ISAM sector has sufficiently broad access to promote sector development. Developing comprehensive policy and regulatory frameworks that address security and commercial growth ensures that engagements protect national security interests without stifling innovation. Such an approach would allow the USSF to manage ISAM collaboration risks effectively, protecting without compromising the sector's growth and innovation capabilities.

Working in partnership with commercial firms, the USSF should also build more public awareness of, and support for, U.S. leadership in space, efforts that will drive both the administration's prioritization of space goals and Congressional funding. Current Pew Research Center surveys highlight some interesting American attitudes about space. For example, two-thirds of Americans continue to think the United States should be global leader in space

exploration.[55] Regarding Americans attitudes towards private companies involved in space exploration and research, the companies generally receive high marks expect for the area of space debris.[56] Moreover, fifty-five percent of Americans think people will routinely travel in space as tourists in the next 50 years.[57] The USSF is uniquely positioned to harness this largely untapped public support to advance its efforts for sustained U.S. superiority in space.

6. Conclusion

The establishment of the USSF represents a transformative development in U.S. national defense and economic strategy, positioning space as a vital domain for innovation and security. By championing initiatives such as ISAM, the USSF can bolster its capabilities and catalyze growth within the burgeoning commercial space sector. Through strategic financial support, regulatory reforms, and robust legal frameworks, the USSF can craft an environment where advanced space operations will flourish safely and sustainably. This proactive approach ensures that the USSF remains at the forefront of space technology and operations. It will also prepare the USSF to navigate the increasingly contested space domain, foster an open yet secure arena for commercial space endeavors, enhance relationships with allies and partners, and expand opportunities in space that will foster closer interagency cooperation to benefit American innovation and long-term economic growth.

Appendix: Case Study: Japan

Like many space-faring nations, Japan's ability to design, provide, and control access to space is a source of national prestige and security. Japan's civil and commercial space capabilities set it apart from many other nations. It has deliberately cultivated and nurtured its existing capabilities while showing intent to increase its military capabilities via recent increases to its budget and changes to its guiding national-level strategy documents.[58] Given competition with the PRC for landing on the moon and in space in general, the U.S. and Japan could mutually benefit from increased partnership in space, to include commercial industry.[59] Recent joint statements by President Biden and Prime Minister Kishida announcing Japan's contribution of a lunar rover and two astronauts to the Artemis moon landing program provide momentum for both countries to build upon.[60]

Japan's defense spending is set to increase to 1.6% of its GDP in fiscal year 2024, measured in FY2022 base year dollars, and it's approved five-year Defense Budget Plan increases the amount to 2% by 2027.[61] However, traditionally Japan has limited its defense spending to 1% of its overall budget, so this doubling of its budget shows significant intent to place emphasis on shoring up its national security, including in space. In addition to its defense budget, Japan recently announced the creation of a ¥81T ($6.53B) fund, to be spent across 10 years, for supporting private commercial space development.[62] The fund's goal is to reduce entry costs for new companies into underdeveloped space market areas. The size of the fund is unprecedented and further shows Japan's intent to accelerate its commercial space industry in support of nascent military operations. A portion of this fund could support further ISAM development by Astroscale Japan and other companies that may be hesitant to enter that market

due to entry costs. Current Astroscale U.S. work with the USSF could aid cross-country leveraging of the investment.[63]

The U.S. must be transparent with Japan and its own stakeholders about the scope and realism of partnership opportunities.[64] Japan's efforts to improve its cybersecurity may need to progress further before the USSF can share space operational and SDA information more fully. However, this barrier should not prevent partnership with Japan, and potentially as South Korea also increases its space budget, the U.S. and Japan should explore resource pooling opportunities considering the countries' recent trilateral partnership. The trilateral commitment to share missile warning data announced last year, for example, could one day become a shared commitment to share SDA and sustainment data.[65]

Endnotes

[1] S2 Headquarters U.S. Space Force Intelligence, "Space Threat Fact Sheet," *Competing in Space*, May 1, 2024, available via United States Space Force "Guardian One" App.
[2] Andrew Jones, "China reorganizes its military, impacts likely for space operations," *Space News*, April 23, 2024, https://spacenews.com/china-reorganizes-its-military-impacts-likely-for-space-operations/.
[3] Office of the Director of National Intelligence, *Annual Threat Assessment of the U.S. Intelligence Community* (Washington, DC: Office of the Director of National Intelligence, 2024), https://www.odni.gov/files/ODNI/documents/assessments/ATA-2024-Unclassified-Report.pdf.
[4] *Ibid.*
[5] Corey Crowell and Sam Bresnick, *Defending the Ultimate High Ground China's Progress Toward Space Resilience and Responsive Launch* (Washington, DC: Center for Security and Emerging Technology, 2023), https://cset.georgetown.edu/publication/defending-the-ultimate-high-ground/.
[6] *Ibid*.
[7] Kristin Burke, "China's SJ-21 Framed as Demonstrating Growing On-Orbit Servicing, Assembly, and Manufacturing (OSAM) Capabilities," *China Aerospace Studies Institute*, December 2021, https://www.airuniversity.af.edu/Portals/10/CASI/documents/Research/Space/2021-12-09%20SJ-21%20and%20China%27s%20OSAM%20Capabilities.pdf.
[8] Office of the Director of National Intelligence, *Annual Threat Assessment of the U.S. Intelligence Community* (Washington, DC: Office of the Director of National Intelligence, 2023), https://www.dni.gov/files/ODNI/documents/assessments/ATA-2023-Unclassified-Report.pdf.
[9] Crowell and Bresnick, 2023.
[10]DOD agencies include the Defense Advanced Research Projects Agency (DARPA), the Air Force Research Laboratory (AFRL), the Naval Research Laboratory (NRL), the Department of the Air Force Rapid Capabilities Office (DAF RCO), the Missile Defense Agency (MDA), and the Defense Innovation Unit (DIU). USSF organizations include the Space Systems Command (SSC), Space Development Agency, Space Rapid Capabilities Office (SpRCO), SpaceWERX, and the Commercial Satellite Communication Office (CSCO). Intelligence community stakeholders include the Intelligence Advanced Research Project Activity (IARPA), the National Reconnaissance Office (NRO), the National Geospatial-Intelligence Agency (NGA), the National Security Agency (NSA), and In-Q-Tel. Because there is no publicly available information from the intelligence community regarding ISAM efforts, this report foregoes discussion of intelligence community stakeholder interests in ISAM. "National Security Space Acquisition Organizations," Aerospace Industries Association, March 25, 2024, https://www.aia-aerospace.org/publications/national-security-space-acquisition-organizations/.
[11] U.S. Department of Defense, *DOD Commercial Space Integration Strategy 2024* (Washington, DC: U.S. Department of Defense, 2024), 1, https://media.defense.gov/2024/Apr/02/2003427610/-1/-1/1/2024-DOD-COMMERCIAL-SPACE-INTEGRATION-STRATEGY.PDF.
[12] U.S. Space Force, *U.S. Space Force Commercial Space Strategy: Accelerating the Purposeful Pursuit of Hybrid Space Architectures* (Washington, DC: U.S. Space Force, 2024), https://www.spaceforce.mil//Portals/2/Documents/Space%20Policy/USSF_Commercial_Space_Strategy.pdf.
[13] Sandra Erwin, "Space Force to Industry: Prove Value of New Commercial Space Services," *Space News*, April 24, 2024, https://spacenews.com/space-force-to-industry-prove-value-of-new-commercial-space-services/.
[14] The White House. *United States Space Priorities Framework* (Washington, DC: The White House, 2021), 5, https://www.whitehouse.gov/wp-content/uploads/2021/12/United-States-Space-Priorities-Framework-_-December-1-2021.pdf.
[15] Anastasia Obis, "Space Force outlines areas for commercial integration," *Federal News Network*, April 23, 2024, https://federalnewsnetwork.com/defense-main/2024/04/space-force-outlines-areas-for-commercial-integration/.
[16] Eric Berger, *Liftoff: Elon Musk and the desperate early days that launched SpaceX* (New York: William Morrow, 2021), 217-221.
[17] National Geospatial-Intelligence Agency, "NGA Commercial GEOINT Strategy," *Medium*, October 27, 2015, https://medium.com/@NGA_GEOINT/nga-commercial-geoint-strategy-57a2465396d3.
[18] Leonard David, "In NASA's Push for the Moon, Commercial Partners Soar—And Stumble," *Scientific American*, March 14, 2024, https://www.scientificamerican.com/article/whats-behind-nasas-commercial-lunar-hits-and-misses/.

[19] Space access, mobility, and logistics (SAML) is a broader category of capabilities that include ISAM. Erwin, "Space Force to Industry."
[20] Sandra Erwin, "U.S. to Pursue Stronger Collaboration with Allies in Military Space Programs," *Space News*, October 11, 2023, https://spacenews.com/u-s-to-pursue-stronger-collaboration-with-allies-in-military-space-programs/ and "FACT SHEET: Strengthening U.S. International Space Partnerships," The White House, December 20, 2023, https://www.whitehouse.gov/briefing-room/statements-releases/2023/12/20/fact-sheet-strengthening-u-s-international-space-partnerships/. Original CSpO members include Australia, Canada, France, Germany, New Zealand, and the United Kingdom.
[21] White House, "FACT SHEET."
[22] *DOD Commercial Space Integration Strategy 2024* and *U.S. Space Force Commercial Space Strategy*.
[23] John A. Tirpak, "The Distillation of the Defense Industry," *Air & Space Forces Magazine*, July 1, 1998, https://www.airandspaceforces.com/article/0798industry/.
[24] "Expanding Integration Across Government and Commercial Space for Speed and Resiliency," The Aerospace Corporation (Chantilly, VA: The Aerospace Corporation), March 5, 2024, https://aerospace.org/article/expanding-integration-across-government-and-commercial-space-speed-and-resiliency.
[25] Keith Hartley, *The Political Economy of Aerospace Industries: A Key Driver of Growth and International Competitiveness?* (Cheltenham, UK: Edward Elgar Publishing, 2014). https://research-ebsco-com.nduezproxy.idm.oclc.org/linkprocessor/plink?id=a1d9df41-527e-3460-a066-d9e46285210a.
[26] Berger, 221.
[27] Office of the Under Secretary of Defense (Comptroller)/Chief Financial Officer, *United States Department of Defense Fiscal Year 2015 Budget Request* (Washington, DC: Department of Defense, 2014), https://comptroller.defense.gov/portals/45/documents/defbudget/fy2015/fy2015_budget_request_overview_book.pdf and Office of the Under Secretary of Defense (Comptroller), *Procurement Programs (P-1): Department of Defense Budget Fiscal Year 2025* (Washington, DC: Department of Defense, 2024), https://comptroller.defense.gov/Portals/45/Documents/defbudget/FY2025/FY2025_p1.pdf
[28] Frank Kendall, B. Chance Saltzman, and David W. Allvin, "Department of the Air Force Posture Statement: Department of the Air Force Presentation to the Committees and Subcommittees of the United States Senate and the House of Representatives 2nd Session, 118th Congress," accessed May 10, 2024, https://www.appropriations.senate.gov/imo/media/doc/download_testimony16.pdf.
[29] Department of the Air Force, *Department of Defense Fiscal Year (FY) 2025 Budget Estimates: March 2024: Air Force Justification Book Volume 1 of 1 Procurement, Space Force* (Washington, DC: Department of the Air Force, 2024), https://www.saffm.hq.af.mil/Portals/84/documents/FY25/FY25%20Space%20Force%20Procurement.pdf?ver=uabQ1iLVb4LqiN2_xgh69A%3d%3d. According to the USSF FY25 RDT&E Budget Item Justification document, SML "identifies and closes space related mobility and logistics capability gaps to facilitate integration and employment of on-orbit servicing and mobility for prepared and unprepared spacecraft and logistics in, from, and through space." SML programs will also provide a mechanism to evaluate and "cultivate" commercial space systems that "have achieved high Technology Readiness Level (TRL) to identify gaps in capabilities and apply emergent technologies."
[30] *Ibid.*
[31] Dale Arney, John Mulvaney, Christina Williams, Christopher Stockdale, Nathanael Gelin, and Paul le Gouellec. *In-space Servicing, Assembly, and Manufacturing (ISAM) State of Play* (NASA Langley Research Center and Analytical Mechanics Associates, Inc., 2023), https://www.nasa.gov/wp-content/uploads/2023/10/isam-state-of-play-2023.pdf.
[32] Jonathan McDowell, "Space Activities in 2023." *Harvard-Smithsonian Center for Astrophysics*, January 15, 2024, https://planet4589.org/space/papers/space23.pdf.
[33] SpaceX, *Falcon Users Guide*, September 2021, https://www.spacex.com/media/falcon-users-guide-2021-09.pdf.
[34] ISAM refueling services here refers both to transferring fuel from one spacecraft to another and to attaching one spacecraft to another, with the new spacecraft providing propulsion and navigation for both craft.
[35] Kristine L. Ferrone, "Majority of Satellites Exceed Design Life," *Aerospace*, December 6, 2019, https://aerospace.org/story/majority-satellites-exceed-design-life.
[36] "Intel Newsroom: Moore's Law," Intel, September 18, 2023, https://www.intel.com/content/www/us/en/newsroom/resources/moores-law.html#gs.8cylkj.
[37] Chester W. Nimitz, *Refueling at Sea, the Secret Weapon*. Naval Historical Center, 1958.

[38] David Vergun, "Spacecom General Wants Satellites With Sustained Maneuverability," U.S. Department of Defense, July 6, 2023, https://www.defense.gov/News/News-Stories/Article/Article/3450313/spacecom-general-wants-satellites-with-sustained-maneuverability/.
[39] United States Space Command, *USSPACECOM Strategic Vision*, February 2024, accessed March 18, 2024, https://www.spacecom.mil/Portals/57/Documents/USSPACECOM%20Strategic%20Vision_Feb%202024%20Online.pdf?ver=INczxf__t9IyetlohPw5dA%3d%3d and John E. Shaw, Daniel R. Bourque, and Marcus Shaw. "Dynamic Space Operations: The New Sustained Space Maneuver Imperative." *Aether*, no. Winter (2023): 8-16.
[40] United States Space Command, USSPACECOM Strategic Vision, February 2024.
[41] "Space Systems." Northrop Grumman. Accessed March 25, 2024. https://www.northropgrumman.com/space.
[42] "Mission Extension Vehicle (MEV)," Northrop Grumman, accessed May 2, 2024, https://cdn.northropgrumman.com/-/media/wp-content/uploads/Mission-Extension-Vehicle-MEV-fact-sheet.pdf?v=1.0.0.
[43] "ELSA-d Mission," Astroscale, March 12, 2021, https://astroscale.com/elsa-d-mission/.
[44] Mitch Hitch, "Is In-Space Maneuvering Tech on the Cusp of a Breakthrough?" *Via Satellite*, April 2024, https://interactive.satellitetoday.com/via/april-2024/is-in-space-maneuvering-tech-on-the-cusp-of-a-breakthrough/.
[45] *Ibid*.
[46]Department of the Air Force, *Space Capstone Publication, Space Power, Doctrine for Space Forces* (Washington, DC: U.S. Headquarters US Space Force, 2020), 28-43.
[47] The absence of a red "X" indicates no change to the level of commercialization.
[48] "Space Spectrum Strategy," *Ofcom,* November 10, 2022, https://www.ofcom.org.uk/__data/assets/pdf_file/0016/241900/ClearSpace-Today-Ltd.pdf and FCC, "Satellite Licensing Division Page," Federal Communications Commission, last updated June 29, 2023, https://www.fcc.gov/satellite-licensing-division-page.The FCC is also responsible for domestic and international spectrum management processes, registers FCC-licensed satellite systems with the International Telecommunications Union (ITU), and advocates for U.S. satellite radiocommunications interests in international fora.
[49] "Space Innovation: Facilitating Capabilities for In-Space Servicing, Assembly, and Manufacturing." Federal Register, March 15, 2024, https://www.federalregister.gov/documents/2024/03/15/2024-05389/space-innovation-facilitating-capabilities-for-in-space-servicing-assembly-and-manufacturing.
[50] "Space Stations," Federal Communications Commission, October 16, 2023, https://www.fcc.gov/space/space-stations.
[51] "Agenda for WRC-23," Federal Communications Commission, May 3, 2024, https://www.fcc.gov/sites/default/files/wrc-23_agenda.pdf.
[52] International Organization for Standardization, "ISO 24330:2024, Information and Documentation — Statistics and Quality Issues for Web Archiving," accessed May 3, 2024, https://www.iso.org/obp/ui/en/#iso:std:iso:24330:ed-1:v1:en.
[53] International Organization for Standardization, "ISO 31000:2022, Risk Management — Guidelines," accessed May 3, 2024, https://www.iso.org/standard/78463.html.
[54] "Space Systems Command Delivers First Hosted Payload to Japan in Historic U.S. Space Force Partnership," Space Systems Command Media Release, January 17, 2023, https://www.ssc.spaceforce.mil/Portals/3/Space%20Systems%20Command%20delivers%20first%20Hosted%20Payload%20to%20Japan%20in%20historic%20U_S_%20Space%20Force%20partnership.pdf.
[55] Brian Kennedy and Alec Tyson, "Americans' Views of Space: U.S. Role, NASA Priorities and Impact of Private Companies." *Pew Research Center,* July 20, 2023, https://www.pewresearch.org/science/2023/07/20/americans-views-of-space-u-s-role-nasa-priorities-and-impact-of-private-companies/.
[56] *Ibid*.
[57] *Ibid*.
[58] Kazuto Suzuki, "Space Security in New Strategy Documents," June 21, 2023, https://www.csis.org/analysis/space-security-japans-new-strategy-documents.
[59] Christian Davenport, "Lunar Relations: The U.S., China and a New Brand of Space Race," *Washington Post*, January 14, 2023, https://www.washingtonpost.com/technology/2023/01/14/china-nasa-moon-space/.
[60] The White House, "Remarks by President Biden and Prime Minister Kishida Fumio of Japan in Joint Press Conference," The White House, April 10, 2024, https://www.whitehouse.gov/briefing-room/speeches-

remarks/2024/04/10/remarks-by-president-biden-and-prime-minister-kishida-fumio-of-japan-in-joint-press-conference/.
[61] Suzuki, "Space Security in Japan's New Strategy Documents."
[62] "Japan Launches $6bn-plus Space Fund to Bolster Private Ventures," *Nikkei Asia*, accessed May 5, 2024, https://asia.nikkei.com/Business/Science/Japan-launches-6bn-plus-space-fund-to-bolster-private-ventures.
[63] Sandra Erwin, "U.S. Space Force and Astroscale to Co-Invest in a Refueling Satellite," *Space News*, September 25, 2023, https://spacenews.com/u-s-space-force-and-astroscale-to-co-invest-in-a-refueling-satellite/.
[64] Andrew Radin and Bruce McClintock, "US Must Be Transparent about Realistic Prospects for Cooperation in Space," *C4ISRNet*, April 12, 2024, https://www.c4isrnet.com/opinion/2024/04/12/us-must-be-transparent-about-realistic-prospects-for-cooperation-in-space/.
[65] The White House, "The Spirit of Camp David: Joint Statement of Japan, the Republic of Korea, and the United States," The White House, August 18, 2023, https://www.whitehouse.gov/briefing-room/statements-releases/2023/08/18/the-spirit-of-camp-david-joint-statement-of-japan-the-republic-of-korea-and-the-united-states/.