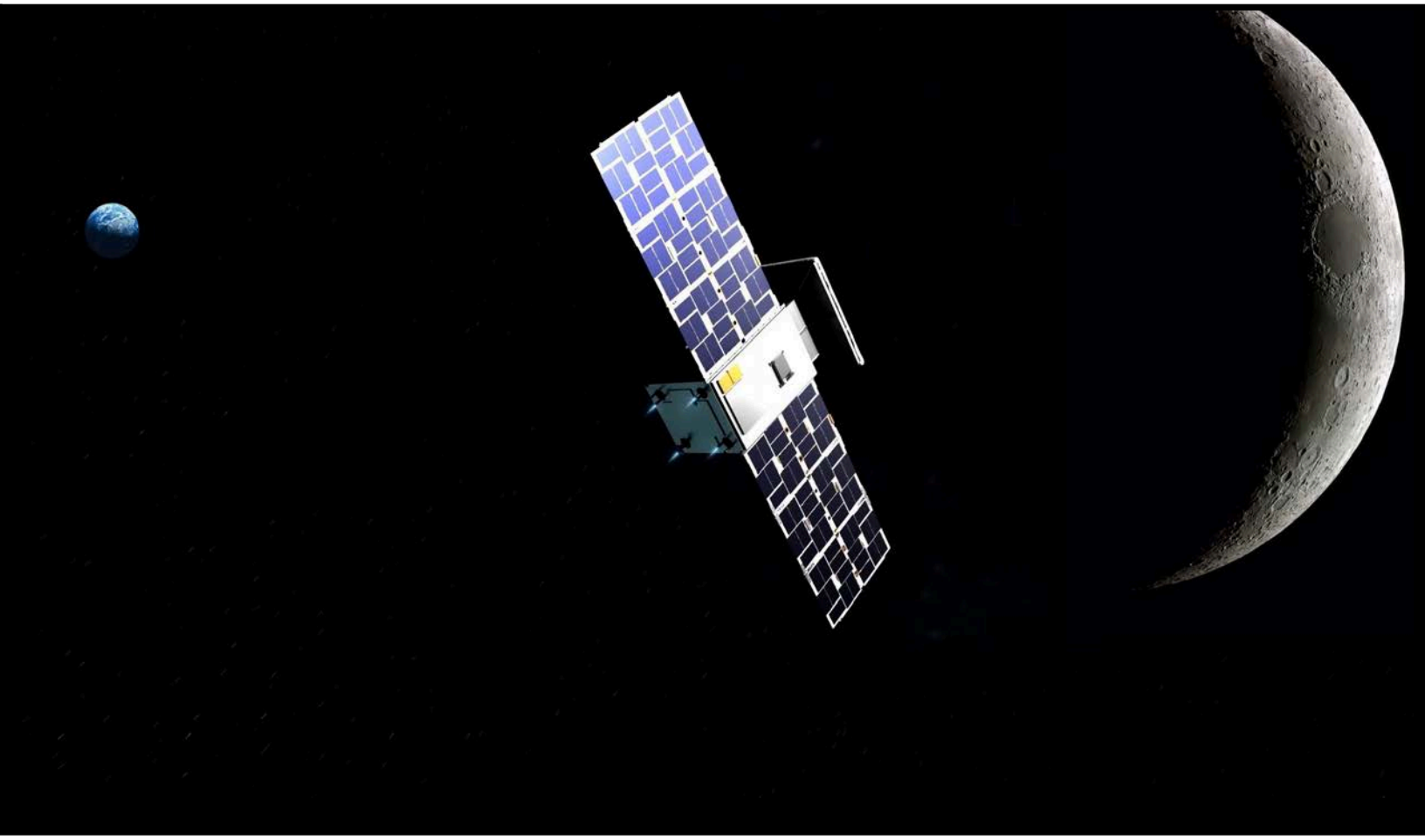

STATE OF THE SPACE INDUSTRIAL BASE 2023

Building Enduring Advantages in Space for Economic Prosperity and Collective Security

Summary Report by:

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Edited By:

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December 2023

DISCLAIMER

The views expressed in this report reflect those of the workshop attendees and do not necessarily reflect the official policy or position of the U.S. Government, the National Aeronautics and Space Administration (NASA), the Department of Commerce (DoC), the Department of Defense (DoD), the U.S. Air Force (USAF), or the U.S. Space Force (USSF). Use of NASA photos in this report does not state or imply the endorsement by NASA, or by any NASA employee, or the DoD, or by any DoD employee, of a commercial product, service, or activity.

Cover: NASA CAPSTONE approaches Near-Rectilinear Halo Orbit as the first commercial Lunar mission used to reduce risk for future spacecraft and operations (Credit: Terran Orbital Corporation)

December 2023

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ABOUT THE KEY GOVERNMENT CONTRIBUTORS

U.S. Space Force | spaceforce.mil

The U.S. Space Force (USSF) is a military service that organizes, trains, and equips space forces in order to protect U.S. and allied interests in space and to provide space capabilities to the joint force. The mission of the USSF is to secure our nation's interests in, from, and to space. USSF responsibilities include developing military space professionals, acquiring military space systems, maturing the military doctrine for space power, and organizing space forces to present to our Combatant Commands.

Air Force Research Laboratory | afrl.af.mil

The Air Force Research Laboratory's mission is leading the discovery, development, and integration of warfighting technologies for our air, space and cyberspace forces. AFRL is headquartered at Wright-Patterson Air Force Base, Ohio with locations in 10 States: California, Florida, Hawaii, Nevada, New Mexico, New York, Ohio, Tennessee, Texas, Virginia, and Washington, D.C. The lab supports external customers and partners with industry while investing in basic research, applied research and advanced technology development. As one integrated lab, AFRL seamlessly supports the Science & Technology needs of two services: the Air Force and the Space Force.

Defense Innovation Unit | diu.mil

The Defense Innovation Unit's (DIU) mission is to accelerate the adoption of commercial technology at speed and scale. It does so by focusing on those solutions that result in the most strategic impact for the joint force, allied and partner forces. DIU's Space Portfolio facilitates the Department of Defense's ability to access and leverage the growing commercial investment in new space to address existing capability gaps, improve decision making, enable a shared common operating picture with allies, and help preserve the United States' superiority in space.

WE WISH TO DEDICATE THIS REPORT

IN MEMORY OF

MARK A. BAIRD

1965 - 2023[1]

Brigadier General (ret.), United State Air Force

Lockheed Martin, Virgin Orbit-National Systems, and York Space Systems

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"I don't have coworkers, I have friends who I have the privilege of serving with."

- MARK A. BAIRD

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[1] Military Times (2023). Mark Baird Obituary. Retrieved from https//www.legacy.com

TABLE OF CONTENTS

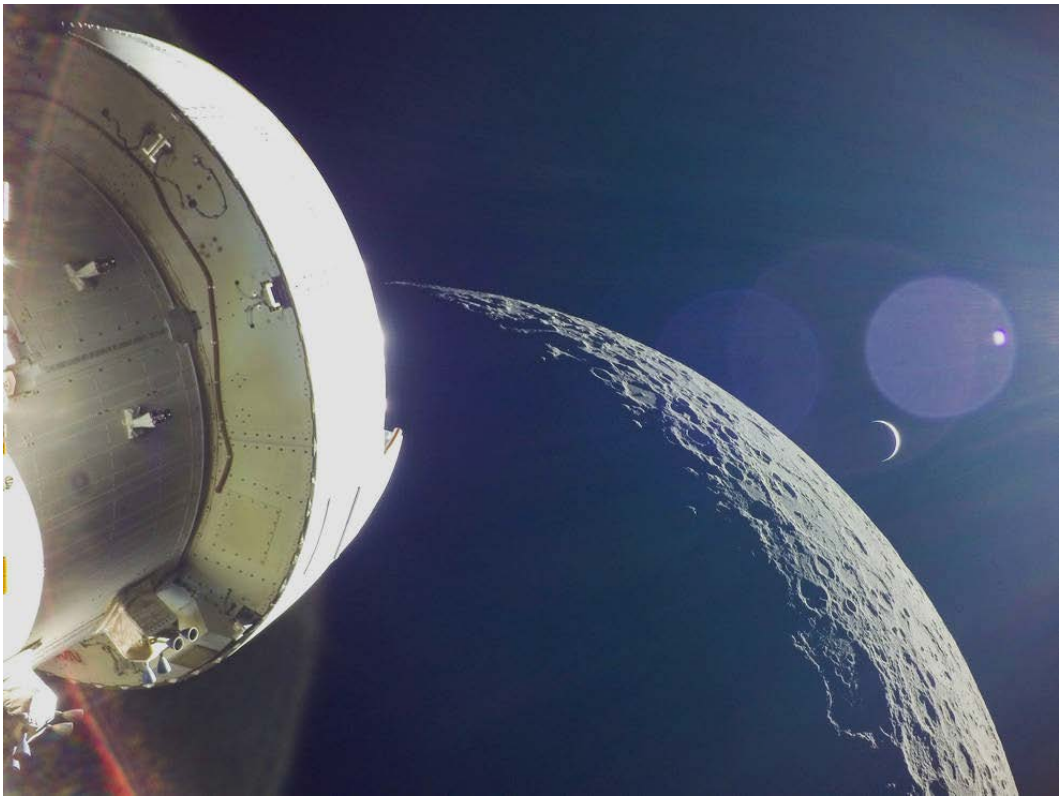

Figure 1. During NASA's Artemis I mission, Orion captured the Earth rising behind the Moon following its second close flyby above the Lunar surface as the spacecraft trekked toward home (Credit: NASA)

"We are now at a historical pivot point in space. Our space industry has proven its ability to do things that once were the sole province of governments, and it is now extending our space economy from low-Earth orbit to Cislunar space. Our global partners also seek to explore the Moon, and thus we will return together, through international and public-private partnerships. And then it's on to Mars."

- BILL NELSON, NASA Administrator, 2023[2]

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[2] NASA (2023). NASA's Moon to Mars Strategy and Objectives Development.

EXECUTIVE SUMMARY

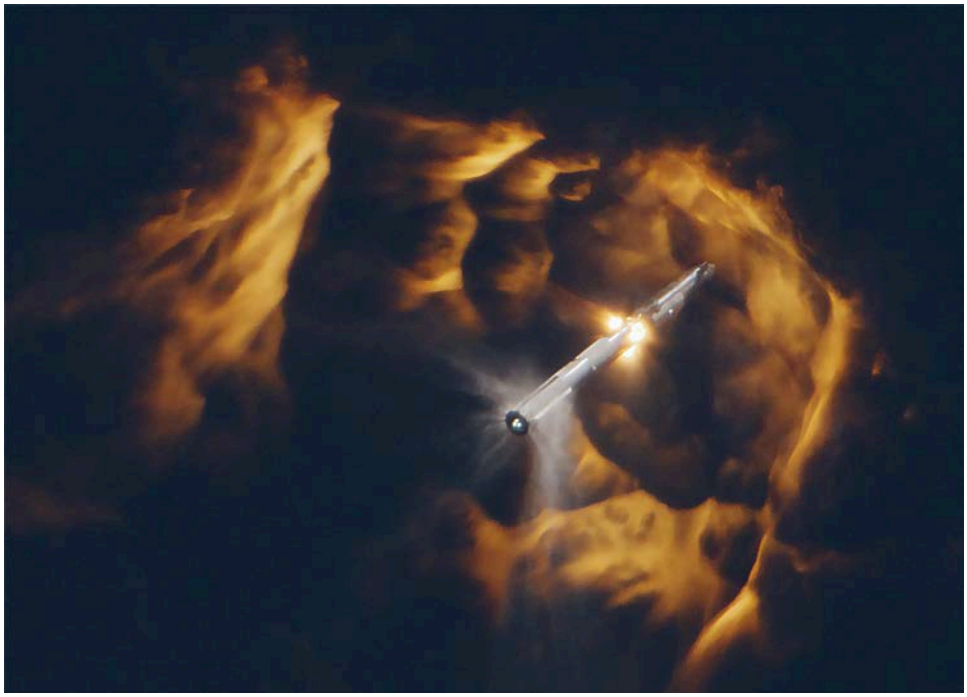

Figure 2. Starship 25 successfully separates from Heavy Booster 9 to demonstrate hot staging during Test Flight 2 from Starbase in Boca Chica, TX. Starship represents a fully reusable transportation system designed to carry both crew and cargo to Earth orbit, the Moon, Mars, and beyond (Credit: SpaceX)

"Space capabilities have become integral to everyday life and a crucial component underpinning the United States' economic prosperity and national security."

– JOHN F. PLUMB, Assistant Secretary of Defense for Space Policy[3]

GENERAL OBSERVATIONS

Major findings from the workshop include:

- **Establish trusted and resilient supply chains** - The U.S. recognizes that resiliency and trusted capacity are the benefits of a healthy and competitive domestic manufacturing and supply base that is responsive in terms of time and scale. Programmatic procurements that extend beyond the current fiscal year provide the stability required to effectively plan and build the workforce, order long lead items and continue to improve technology in an agile way. The ability to domestically produce these and other dual-use national security capabilities at scale contributes to an integrated deterrence and is foundational to peace through strength.

[3] DoD (2023). DoD Prioritizing Cooperation With Allies in Space. DoD.

- **Streamline the Bureaucracy** - Regulatory and licensing agencies within the U.S. Government must be resourced and incentivized to facilitate innovative and agile approaches to address both the growing number of licensing requests as well as the accelerated need for policy evolution in order to maintain pace with competitors and technological advancement. Bureaucratic inefficiency stifles innovation and places U.S. space leadership at risk.
- **Improve access to Financial Tools** - The most innovative and technologically advanced solutions developed privately within the U.S. today require the most appropriate and timely financial tools that permit the accelerated development and fielding of new capabilities at a speed and scale to sustain U.S. leadership in space. The Special Purpose Acquisition Company (SPAC) transaction as a means to raise funding in public markets for early-stage companies has not served the nation well. The appropriate commoditization of space products, services and resources by economists (not engineers) must be deliberately planned and executed in a manner that stabilizes capital investment and significantly reduces risk imposed by boutique financial deals.
- **Team with Global Partners** - U.S. space systems and architectures should be Allied-by-Design which allows our partners to equally benefit in terms of their participation in economic prosperity and collective security on a global scale. The challenges posed by adversaries today are much smaller when allies stand shoulder-to-shoulder with integrated space capabilities. This is the first SSIB report to include the results of a Global Partnership Working Group which convened in May at the Naval Postgraduate School in Monterey, CA.

Central message from inputs - The U.S. must continue to leverage the most advanced commercial space capabilities at speed and scale to achieve its strategic objectives in science, commerce and national security while lowering the temperature of conflict globally. These are not mutually objective goals; rather, they are complementary and inextricably linked.

Major themes from participants - Continued non-dilutive investments by the DoD, NASA, Department of Commerce, and other government agencies with space equities are essential to the success of the new space economy. Actions that accelerate the transition from prototype transactions to "meaningful contracts" for procurement of hardware, software or services is key to sustaining the interest of private investors who have made billions of dollars of early-stage investments into technologies of significant interest to our national security.

Major opportunities - The accelerated advancement of high cadence, reusable, heavy lift launch capability is paramount to achieving a sustainable path to economic prosperity and collective security. 2024 may prove to be the pivotal year in setting the conditions for either expanded U.S. market leadership or retreat in this very competitive global sector--and critical area to both the future space economy and national security. Likewise, the opportunities provided by the new trilateral security partnership agreement between Australia, the United Kingdom and the United States (AUKUS)[4] and similar bilateral agreements with other partners must be acted upon to establish the beginning of a

[4] DoD (2023). AUKUS: The Trilateral Security Partnership Between Australia, U.K. and U.S.. DoD.

global network of spaceports that assure space launch resiliency and broader access to the new space economy.

Major concerns requiring urgent action - The normalization of continuing resolutions in lieu of on-time budget appropriations year-after-year continues to challenge our nation's ability to modernize and out-pace peer competitors across the dimensions of commercial, civil and national security space. The nascent nature of the new space economy combined with the prevalence of both civil and defense market share provides little margin to assure the long-term viability of the space industrial base

A need to act and accelerate progress on previous recommendations - A significant number of highly relevant space strategy and policy documents have been published spanning two Administrations and their National Space Councils. A whole-of-nation commitment is required to make these visionary positions into reality. Continued bipartisan support for commercial, civil and national security space with our allies and global partners by our side is imperative to shaping a space future that is good for peace, freedom, prosperity and sustainability.

"We will be a fast-follower where market forces are driving commercialization of military-relevant capabilities in trusted artificial intelligence and autonomy, integrated network systems-of-systems, microelectronics, space, renewable energy generation and storage, and human-machine interfaces."

- 2022 NATIONAL DEFENSE STRATEGY[5]

KEY ACTIONS & RECOMMENDATIONS

These recommendations reflect the numerous inputs from workshop participants and their best assessment regarding how to influence or affect change:

1. **Embrace a Collective North Star Vision for the U.S. and its Global Partners.** The US must create a safe, stable, secure, and sustainable space domain which builds and advances an enduring competitive advantage for the United States and its global partners for economic prosperity and collective security in pursuit of national goals that embrace the peaceful economic development and human settlement of space in a manner that is consistent with our shared values, democratic principles and appreciation for both human rights and the environment.
2. **Accelerate Transition to Dynamic Space Operations.** The U.S. must create capabilities for the conduct of operations which can respond to challenges in the space operating environment in a rapid and agile manner at scale. This includes responsive spacecraft and payload development and integration, responsive space access not only to orbit but to all areas of U.S. interest, sustained maneuver, and the ability to resiliently re-allocate within and across constellations.

[5] DoD (2022). 2022 National Defense Strategy of the United States of America.

3. **A Shift toward Agile Policy Making and Execution**. We are immersed in a Fourth Industrial Revolution highlighted by accelerated change in the advancement of new technologies. Policy and precedent must maintain pace so that the U.S. and its global partners remain leaders in establishing global standards, norms, and practices consistent with U.S. National Policy, strategy, and objectives outlined in the Space Framework. Policy must outpace innovation, or else the U.S. will concede its competitive advantage for the sake of bureaucratic convenience.
4. **Development and Production at Speed and Scale**. Fast following commercial technology to achieve strategic outcomes requires timely, effective, streamlined, flexible, and enabling contracts, procurement approaches, architectures, digital systems engineering practices, funding paradigms, collaborative development efforts, rapid prototyping, concurrent engineering, and active technology demand pull to fully harness and leverage commercial speed, scope, scale, and production capacity to compete economically while contributing to integrated deterrence.
5. **Address Bureaucratic Delay.** The U.S. needs to incentivize private investment in the space economy so that the USG doesn't have to carry the full burden, but bureaucratic delay (including delays in launch and re-entry licenses per FAA Part 450) destroys or drives away private investment and U.S. competitive advantage. Bureaucratic delays in licensing and permitting are the single most self-defeating--and addressable problem across the space enterprise.
6. **Sustained Funding for Programs that Leverage Commercial Solutions.** Examples include the Space Development Agency Proliferated Warfighting Space Architecture, Artemis, Hybrid Space Architecture, Tactically Responsive Space (TacRS), xGEO and Cislunar Space Domain Awareness partnerships, and many others.
7. **Protection of Space Commerce.** A continuum of conflict from competitive, through crisis, and conflict, exists today where space systems, networks, ground stations and infrastructure are all experiencing cyber attacks or are at risk of physical damage through the actions of peer competitors and criminal enterprises. Peacetime is 'all the time' which requires protection of commercial capabilities that contribute to the growing space economy. Integrated deterrence begins with the protection of our national interests across all domains including space.
8. **Supply Chain Trust and Resiliency.** A dynamic, robust, diverse, resilient, innovation-driven, and scalable supply chain, industrial base, and entrepreneurial ecosystem are essential to achieve and sustain our national goals and objectives in space.
9. **In order to save the planet, we must get off-planet.** Advancements in space power production, manufacturing, connectivity, and Lunar resource extraction will be foundational to creating and powering the future multi-trillion-dollar space economy. In order to lead, enabling new and evolved strategy, policy, and law, perhaps even treaties, are required. Activities and human presence in space should be driven by an international rules-based order and systems that uphold liberty and prosperity for all humankind.

INTRODUCTION

"It is difficult to say what is impossible, for the dream of yesterday is the hope of today and the reality of tomorrow."

- ROBERT H. GODDARD, American Rocketry Pioneer

We stand on the shoulders of giants. The unprecedented growth in technological achievement, scientific discovery and economic opportunity made possible in space today can be attributed, in large part, to the tenacious pursuit of 'the impossible' by predecessors who established the foundation for present day success. Likewise, the unrelenting pace of innovation today led by visionary entrepreneurs, tireless engineers and insightful private investors, continues to build upon and strengthen this bedrock of experience for a more promising future. This foundation of knowledge, talent, investment and partnership forged over time continues to diversify and grow our space industrial base in both capability and capacity as humankind reaches for the Moon then Mars and beyond. This is the process by which enduring advantages are achieved, sustained and shared with allies, partners and friends who aspire toward a common North Star Vision of economic development and human settlement in space.

The American space journey began in 1926 when Dr. Robert Goddard successfully launched the first liquid fuel rocket from Auburn, Massachusetts. In much the same way that the Wright Brothers first flight was viewed 23 years earlier, the 2.5 second, 41-foot ascent of Goddard's rocket drew as much interest as the 12 second, 180 foot flight of the Kitty Hawk before it. Fortunately for us, Goddard (like the Wrights before him) was not dissuaded by the bureaucratic rigidity of his contemporaries. Today, commercial aviation contributes $3.4 trillion to the global economy,[6] while the fledgling commercial space economy grew 8% to $0.55 trillion with 41% projected growth over the next five years.[7] Building enduring advantages today contributes to economic prosperity tomorrow.

Figure 3. Dr. Robert Goddard at his Roswell, New Mexico workshop in 1935 (Credit: NASA)

Building enduring advantages is also a primary objective through which the Department of Defense advances its goals under the 2022 National Defense Strategy, which also calls on the Department to incorporate allies and partners at every stage of defense planning in all domains – including space.[8] Such cooperation seeks to develop and maintain a robust, interoperable space infrastructure to enable joint and combined operations in all domains. We therefore must be able to integrate, plan, and operate with

[6] Airlines for America (2023). Economic Impact of Commercial Aviation.
[7] Grush, L. & Kendall, T. (2023). Global Space Spending Is Projected to Grow 41% Over the Next Five Years. Bloomberg
[8] DoD (2023). Space Policy Review and Strategy on Protection of Satellites.

our most capable allies in the space domain today, and there is no better means of doing so than with commercial space technology. Building enduring advantages with allies and partners today contributes to our collective security tomorrow.

The theme of this year's State of the Space Industrial Base (SSIB) report appropriately captures the necessity of doing both. Building enduring advantages in space begins with global partnerships driven by the goal of building enduring relationships forged on trust. This also includes the pursuit of transformative space capabilities with focus, speed and scale. The recommendations for actions in this report are required to achieve a shared vision for economic prosperity and collective security against a growing number of natural and manmade threats today. They encompass the dreams of yesterday, the hope of today, and the best path to the reality of tomorrow.

PURPOSE

The State of the Space Industrial Base (SSIB) workshop is an annual meeting to assess progress and provide input and recommendations for the U.S. on its journey to secure the space future that honors commitments made in our Constitution to provide for the common defense, promote the general welfare, and secure the blessings of liberty to ourselves and our posterity. It solicits direct feedback from the U.S. space industrial base, investors, analysts, thought leaders and other stakeholders to assess our progress, suggest paths of synergy to build enduring national advantage, sustain and expand the space industrial base and broader national security innovation base. It is meant to provide actionable recommendations to actors in the space ecosystem enabled by leaders across the entirety of U.S. society as well as those of our closest allies and partners.

"It is a fact: we're in a space race; and it is true that we better watch out that they don't get to a place on the Moon under the guise of scientific research. And it is not beyond the realm of possibility that they say, 'Keep out, we're here, this is our territory.'"

\- BILL NELSON, NASA ADMINISTRATOR, 2023[9]

WORKSHOP OBJECTIVES

Competing with the Goal of Sustainably Winning the New Space Race. This workshop continues to assess the United States' progress toward preferred futures identified in *The Future of Space 2060 and Implications for U.S. Strategy*[10] which cautioned, "The U.S. must recognize that in 2060, space will be a major engine of national political, economic, and military power for whichever nations best organize and operate to exploit that potential."[11] The report defined the preferred future as one of thriving off-Earth human communities, a vastly expanded and self-sustaining economic sphere, with a balance of power that favors U.S. leadership in shaping a free and open system. As noted in the previous year, "what's at stake is no less than whether the largest geographic zone of human activity is one of

[9] Bender, B. (2023). 'We better watch out': NASA boss sounds alarm on Chinese moon ambitions. Politico.
[10] Mozer, J. (2019). The Future Of Space 2060 & Implications For U.S. Strategy. DTIC.
[11] Air Force Space Command (2016). The Future of Space 2060 & Implications for U.S. Strategy.

democratic freedom and fair trade, or an autocratic exclusion zone."[12] Winning is not compromising, and certainly does not mean conceding. To sustainably *win* the new space race is to determine the conditions for which future generations may inherit not just the technological achievements of our day, but the preservation of our values, a free and open society, a free market economy, and the right of self-determination free from tyranny and oppression. This is an enduring and worthy pursuit. As stated in previous reports, we must not become China to beat China; rather, we simply need to be more American to remain American. The latter infers that we must relentlessly challenge ourselves with new ideas that disrupt the status quo at speed and scale necessary to compete and win. We will not succeed without accepting risk and learning rapidly from failure. History reinforces the American ethos that winning requires us to stand on the shoulders of giants like Robert Goddard from yesterday, while fanning the flames of the new giants of tomorrow.

Progress Toward A North Star Vision. This year has seen substantial progress toward the goal of shaping a vastly expanded and self-sustaining space economy, laying the first pave stones for thriving off-Earth human presence beyond the International Space Station, and establishing a balance of power that favors U.S. and allied leadership in shaping a free and open system based on a North Star Vision of economic development and human settlement championed by the participants of the previous three workshops and reports. As observed in our first ever Global Partnerships workshop, the call for a grand strategy in space is shared by our closest allies and partners who recognize the necessity and wish to participate in the journey.

A Decisive Decade - The White House has called this the 'decisive decade' where the People's Republic of China (PRC) remains our most consequential strategic competitor for the coming decades and the only country with both the intent to reshape the international order, and, increasingly, the economic, diplomatic, military, and technological power to do so, and is taking "increasingly coercive actions to reshape the IndoPacific and international system to fit its authoritarian preferences."[13] As such, the Department has been asked to focus on "safeguarding and advancing vital U.S. national interests" which include protecting the security of the American people, expanding economic prosperity and opportunity, and realizing and defending the values at the heart of the American way of life. Thus, the National Defense Strategy calls for the United States to build enduring advantages across five lines of effort:[14]

- Transform the foundation of the future force by rewarding rapid experimentation
- Make the right technology investments
- Adapt and fortify our defense ecosystem
- Strengthen resilience and adaptability
- Cultivate the workforce we need

This year's SSIB report examines how the space industrial base is contributing to such enduring advantages while fostering others, and what actions can be taken to remove obstacles and further accelerate and fortify a collective defense ecosystem that leverages commercial space technology and a globally trusted and resilient supply chain. Foremost in achieving these objectives is the recognition

[12] DIU (2021). State of the Space Industrial Base 2021 Infrastructure & Services for Economic Growth & National Security.
[13] DoD (2022). National Defense Strategy of the United States of America.
[14] Ibid.

that we must also sustain enduring advantages that aid the United States and its allies in retaining leadership in space.

CURRENT STATE

Subjective Survey Results - Participants at the main workshop in Albuquerque, NM were asked to provide a subjective assessment of the health of various parts of the space industrial sector (see Figure 4). Seventy percent of the respondents represented the industrial base whereas the balance were primarily government. Attendees were overwhelmingly bullish on growth, innovation, technology, entrepreneurship, atmospherics and enterprise view. However, they were most bearish on the subjects of incentives, domestic supply chain and legislation. While some have speculated that private investment in space has 'dried up,' the survey is rather ambivalent to the matter with a small minority seeing a decline in capital access. Notably, access to human capital is a key area of concern reflecting a downward trend since last year. While tax incentives vary from state to state, recent changes in the federal tax code have imposed limits on the aerospace industry's ability to write off research and development expenses incurred while pursuing innovation.[15] Legislation scored poorly as fiscal year 2023 started with a delayed federal budget appropriation that was finally passed on December 23, 2022.

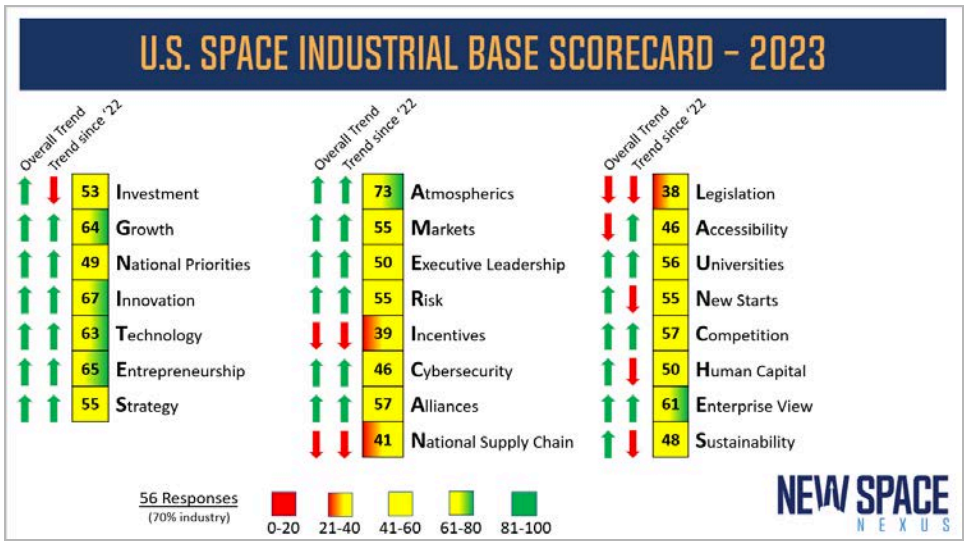

Figure 4. Subjective survey results from workshop participants in Albuquerque, NM (Credit: New Space Nexus)

QUALITATIVE ASSESSMENT

Access to Space - Calendar year 2022 was record-breaking with a total of 186 orbital space launches deploying 2,521 total spacecraft.[16] Eight of those launches resulted in failures accounting for an accumulative 95.7% success rate. The United States sustained its lead with 87 (47.7%) of the launches, followed by China in second place with 64 (34.4%) and Russia in third place with 21 (11.2%) (See Figure 5). As this report goes to publication the United States has already exceeded the previous year's performance in 2023 by 33% (See Figure 6).

[15] AIA (2023). Tax Day Looms: Aerospace and Defense Industry Calls for Urgent R&D Tax Code Reform.
[16] BryceTech (2023). 2022 Orbital Launches Year in Review.

Total Upmass - A grand total of 1,013,034 kg (1,013 metric tons) of mass was launched into space in 2022 - another first for spaceflight.[17] The U.S. led with 714,582 kg or 70.5% of total upmass, followed by China with 185,496 kg (18.3%), and then Russia with 69,963 kg (6.9%). SpaceX alone launched 629,459 kg or 62.1% of the total upmass globally, and 88% of the upmass nationally.

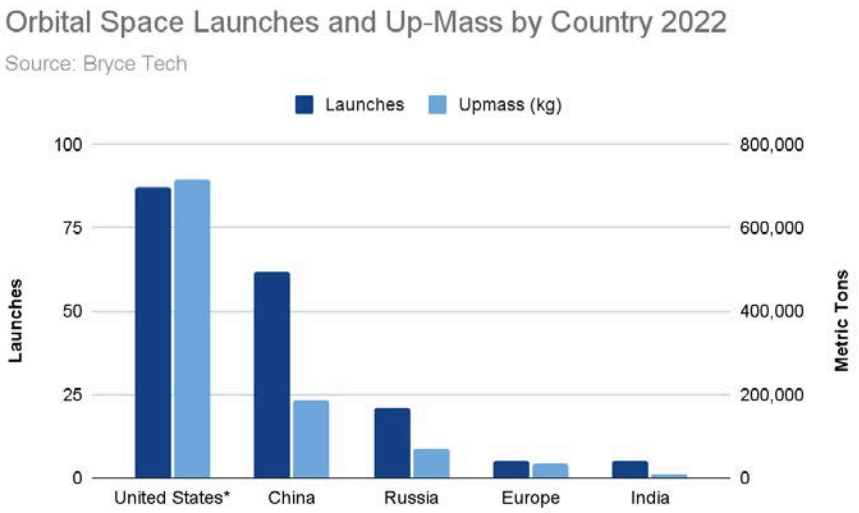

Figure 5. The United States delivered 200% more mass to orbit in 2022 than it did in 2021. China's performance was unchanged from the previous year. (*New Zealand launches are counted in U.S. figures / Credit: DIU)

Despite the United States' strong showing in 2022, it is important to note that China and Russia continue to challenge the U.S. when their numbers are combined. Accelerated development and fielding of new, reusable launch vehicles (e.g. Starship, New Glenn, Terran R, Neutron, Vulcan, and others) is critical to sustaining an enduring advantage with regard to high cadence and responsive space access. Sustained growth is asymptotic with the capacity of existing spaceports and infrastructure.

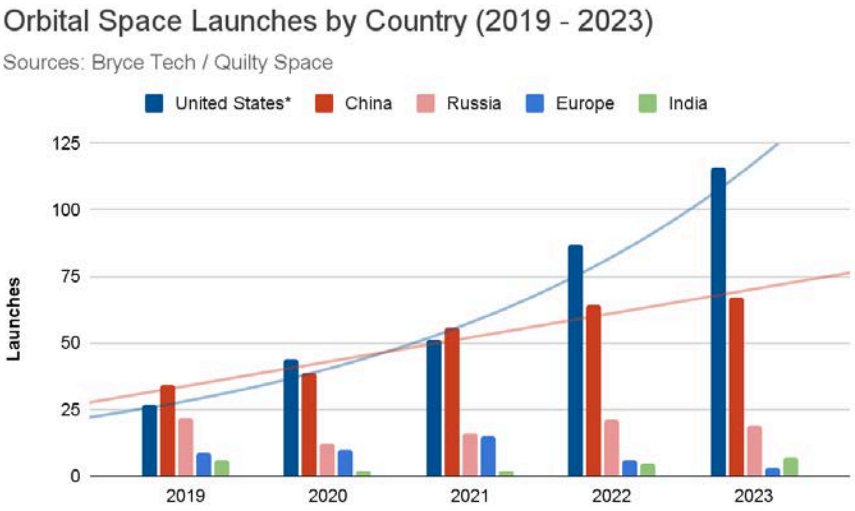

Figure 6. A five-year trend of orbital launches by country reflects growing U.S. lead in space access. A little more than 90% of those launches were performed by SpaceX in 2023. (Credit: DIU)

[17] BryceTech (2022). Global Orbital Space Launches Q1 through Q4 2022.

Satellite mass trending upwards - As the global demand for commercial space services grows, so does the size and mass of buses to address this need. This was the finding of a detailed analysis by Quilty Space[18] that forecasts tempered growth in the production and deployment of commercial satellites based on a critical analysis of today's commercial space sector and the viability of the companies to actually deliver on them (see Figure 7).

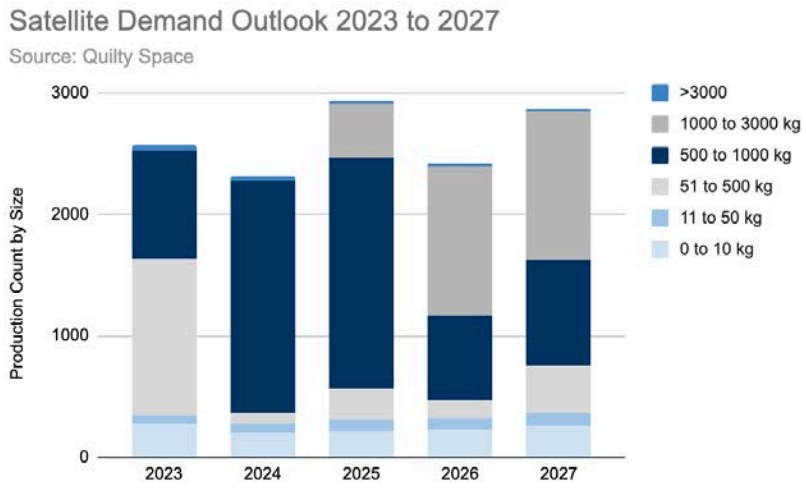

Figure 7. Forecast of satellite demand and launch class (by mass). [Note: Data excludes filings by E-Space, Russian Federation and the People's Republic of China.] Source: Quilty Space

Cost per kilogram to orbit - A McKinsey & Company analysis of space launches revealed a significant reduction in the cost of heavy launches to LEO with prices falling from $65,000 to $1,500 per kilogram - a 95% reduction.[19] Despite the allure, most satellites and other spacecraft must be inserted into very specific 'mission designed' versus 'rideshare' orbit profiles which are better for business as well as space traffic management.

Revenue Generation - The single most important metric reflecting the health of the U.S. commercial industrial base is revenue. Since most of the companies are privately owned, it is difficult to provide a full accounting. That said, it is noteworthy that SpaceX turned a profit of $55 million on $1.5 billion in revenue in the first quarter of 2023.[20] They are not alone, but certainly the biggest of the new space startups to disrupt the aerospace industry. This is very significant as investors look toward profitability to fuel future investments in commercial space. Revenue reflects demand and the competitive ability to capture it. As an early adopter and significant user of commercial space products, software and services, the U.S. Government benefits from articulating and acting on those needs as both NASA and USSF have done to date. Yet, the commercial scaling of these capabilities ultimately requires a competitive alignment with commerce on a global scale. The DoD's procurement of products, software and services as they are offered commercially only helps to advance that goal.

[18] Quilty Space (2023). Satellite Demand Outlook: 2023 to 2030 Report. Quilty Space.
[19] Daehnick, C., Gang, J. & Rozenkopf, I. (2023). Space launch: Are we heading for oversupply or a shortfall? McKinsey & Co.
[20] Maidenberg, M. (2023). A Rare Look Into the Finances of Elon Musk's Secretive SpaceX. Wall Street Journal.

Growth of the Global Space Economy - The global space economy grew by 8% in 2022 to $546B while governments spent an additional $9 billion on space, raising the percentage of defense spending in government budgets to 45% in 2022 compared to 41% in 2021.[21] Despite recent market turbulence, the space economy is expected to sustain growth over the coming years. The greatest investors in the new space economy are not space companies; rather, they are Fortune 500 companies who understand how to turn new space capabilities into products, software and services that give them a strategic advantage in the global marketplace.

According to Euroconsult Group, 2023 was a record-breaking year, where total government space budgets reached $117 billion. There was an almost even split between defense space spending (50.2% or $58.8B) and civil space spending (49.8% or $58.3), with a notable surge to a total of $13.2B being spent on Space Security and Early Warning. Of note, the U.S. led investment with a total of $73B, though its relative share has dropped significantly between 2000 and 2023 from 75% to just 63% of global expenditures, while China has risen to the 2nd position ($14B), Japan 3rd ($4.7B), followed by France ($3.5B), Russia ($3.4B).[22]

McKinsey & Co analysis determined that roughly 27,000 active satellites will orbit by 2030 requiring 4,000 to 5,000 satellites to be launched annually just to maintain these constellations.[23] Conservatively, that is a 40-fold increase in the number of U.S. commercial launches estimated to occur in 2023 alone (of which SpaceX executed 96 launches). Clearly, launch reliability and responsiveness will continue to be of utmost importance. If all of the currently planned constellations were to be successful, these numbers could more than double and require the delivery of 15,000 metric tons of mass to space - that's 15 times more than we achieved in 2022--and mostly with Falcon 9s. Launch demand may vary based on need, but no current estimates reflect a decline in launches required annually. The more meaningful question is "will the U.S. retain its leadership in orbital space launch with only six operational spaceports in the continental U.S. and a licensing process that is ill-equipped and under-resourced for scale? Our global competitors are betting on just that.

The People's Republic of China - The Center for Security and Emerging Technology (CSET) published an excellent issue brief this summer focused on China's progress toward space resilience and responsive launch. In this report, the authors make significant observations based upon evidence obtained from open sources:[24]

- In the past four years alone, China has nearly doubled the total number of satellites it has placed in orbit since first successfully launching a satellite in 1970.
- China is placing its new satellites in a diverse set of orbital regions including the Queqiao communications satellite in Cislunar space beyond the Moon in 2018; and more recently, two Shiyan experimental satellites in Molniya (elliptical) orbits that offers extended coverage over

[21] Space Foundation Editorial Team (2023). Space Foundation releases the Space Report 2023 Q2, showing annual growth of global space economy to $546B. Space Foundation.
[22] Euroconsult (2023). Government Space Programs, 23rd edition.
[23] Ibid (14).
[24] Crowell, C. and Bresnick, S. (2023). Defending the Ultimate High Ground: China's Progress Toward Space Resilience and Responsive Launch. CSET.

Earth's North Pole. Both of these accomplishments were technological firsts ahead of the U.S. and its allies.

- Over the past six years, China has doubled the total number of orbital-class launches since its first in 1970. They have constructed a fourth launch complex and introduced five new liquid-fuel and eleven new solid-fuel launch vehicles during the past decade.

- Most notably, China has prioritized continued development of a tactically responsive launch capability that it first demonstrated in 2013. The Space Force only recently completed the successful VICTUS NOX mission depicted in Figure 3 (page 4).

Figure 8. The SQX-2Y rocket blasts off from the Jiuquan Satellite Launch Center. Source: iSpace[25]

Fast Follower Mandate - The 2022 National Defense Strategy codifies that "*[The United States] will be a fast-follower where market forces are driving the commercialization of militarily-relevant capabilities... and [DoD] will speed their delivery to the warfighter.*"[26] Being a fast-follower requires that the DoD rapidly fields new capabilities that remain tightly coupled to the current state-of-the-art in technology being explored by both commercial industry, and academia. To do so, it must be an early adopter of disruptive new technologies developed by first movers, and it must fast-follow the industrial base that turns these innovations into new capabilities at speed and scale.

GENERAL OBSERVATIONS

At present, there are four key observations requiring immediate attention to fuel our collective industrial base, retain its pace of innovation, and flourish in terms of new capabilities, jobs and contribution to our gross domestic product: (1) streamline the bureaucracy, (2) improving access to financial tools; (3) teaming with global partners; and (4) establishing trusted supply chains that are both responsive in terms of time, scope, and scale.

[25] CGTN (2023). Tech breakthroughs boost China's commercial space industry development. CGTN
[26] DoD (2022). 2022 National Defense Strategy of the United States of America.

STREAMLINE THE BUREAUCRACY

Bureaucratic Inefficiency Stifles U.S. Space Innovation and Competitiveness - The U.S. Congress recently heard testimony from U.S. space companies who are iterating new and improved versions of their technology much faster than the bureaucracy can license them to fly it.[27] As a result, these delays impede risk reduction, adversely affect revenue generation, and forfeit one of the most valued commodities in a global competition: time. The policies that govern the commercial space industry were largely written for a former era of great power competition where the U.S. Government was the leader in research and development (R&D) expenditures and the innovation that stemmed from it. Today, it is the commercial sector that dominates both. Yet the commercial space regulatory and licensing processes remain decentralized, overly bureaucratic and slow-by-design. Unity of Command and Effort is required for regulatory efficiency and effectiveness. The employees in these agencies are insufficiently numerous and resourced to handle the growing workload with tools reminiscent of 1983 rather than 2023. In the absence of streamlining and centralizing authorities that govern the very nascent commercial space sector, we risk losing it. An untenable consequence given that the PRC is ready to step in and dominate in the wake of such a collapse. Space companies are very expensive with monthly expenditures that are often measured in hundreds of thousands (satellites) or even millions of dollars (launch). That is one of the reasons why the most successful of these firms are backed by billionaires armed with patient capital. The new space sector that was born a little more than a decade ago has endured the pandemic, banking crises, and inflation. Despite this, the golden hour to revive it may be upon us.[28] Bureaucratic inefficiency may not be the cause, but may certainly prove to be the death nail for the emerging space economy that holds so much potential for the future.

"If we want to be a leader in space, I feel an unbelievable pressure to fly as soon as we can fly and learn as much as we can. So, we're trying to move. We've got a lot of challenges in front of us to meet the requirements we received from NASA. The only way we can get there is by flying."

\- BILL GERSTENMAIER, SPACEX[29]

Focus, Speed and Scale - In April of this year, Secretary of Defense Lloyd Austin took decisive action to 'sustain and strengthen' integrated deterrence against the pacing challenges of the PRC, and acute threats such as Russia, by sharpening the Joint Force's technological edge.[30] In his memo addressed to senior Pentagon leadership, the combatant commanders and others, Secretary Austin detailed the need to accelerate the adoption of commercial technology 'at speed and scale.' In order to accomplish this, he realigned the Defense Innovation Unit (DIU) to report directly to him with its Director serving as a senior advisor and catalyst for engagement and investment in private sector communities where commercial technology can be adapted and applied to meet warfighter requirements.

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[27] Sheetz, M. (2023). SpaceX, Blue Origin, Virgin Galactic executives urge senators to improve the FAA. CNBC.
[28] The Golden Hour standard is used in emergency medicine and trauma care and states a person must receive definitive care within one hour to ensure optimal outcomes.
[29] Foust, J. (2023). SpaceX frustrated by Starship licensing delays. SpaceNews.
[30] Austin, L. (2023). Memorandum: Realignment and Management of the Defense Innovation Unit. DoD.

Time for a U.S. Department of Space or National Space Agency? - It may be time for the U.S. to centralize the authorities to regulate, advocate and orchestrate national interests in space under a single department or Agency with a cabinet level secretary - but only when the conditions are most appropriate for its assured success. If a Department of Space or National Space Agency was established, the participants recommended that it should follow in the tradition of the Department of Energy (DoE) wherein the Executive retains the ability to act decisively, control costs, accelerate strategic programs, and achieve impact where most immediate. This approach is properly aligned with the national imperative of retaining U.S. leadership in commercial, civil and national security space in light of the on-going strategic competition with the PRC, Russia and other emerging space powers. Until such time as this happens, a concerted effort to streamline the bureaucracy under the Vice President, or an appointed Director of Space, is needed to assure the preservation of the space industrial base, continued growth of the workforce and the economic benefit it will unleash in the decades to come.

A tale of two Departments - The DoE was established in 1977 with a focus on both national security and economic prosperity.[31] It was deliberately planned over many years and served to consolidate numerous large and small bureaucratic activities under one roof with one boss who happened to have a seat on the President's Cabinet. In the end, the Executive Branch exercises singular control over the advanced energy enterprise for both defense and economic security. Conversely, the Department of Homeland Security (DHS) was created in crisis following the 9/11 terrorist attacks. The establishment of DHS hastily consolidated 22 agencies under Congressional control with a focus on preventing further attacks. While DHS has been successful in its primary mission, it continues to operate under the full weight of the bureaucracy and despite numerous deficiencies (i.e. integration with the intelligence community) that are well documented.[32] With these histories in mind, the participants agreed that it should be clear that the deliberate design and implementation of a U.S. Department of Space or National Space Agency would be preferable.

A Software-Defined Approach to Regulatory Licensing - The most immediate solution to the problem of bureaucratic delay can be achieved through automation leveraging cloud-based software applications, state-of-the-art modeling and simulation tools, and secure access to proprietary data using the most advanced methods of cybersecurity that are commonplace in the commercial sector. The funding of this capability should be a national priority with the goal of reducing licensing from months to days while enabling real-time coordination and collaboration between disparate agencies. Accelerating the development, test and fielding of this capability should be an interagency endeavor that extends to support the licensing of launch, spectrum, environmental and other activities with allied and partner capabilities as well.

IMPROVING ACCESS TO FINANCIAL TOOLS

WANTED: Space Economists - The extent of technological innovation and the resulting commercial achievement reflected across the space engineering enterprise today is unprecedented. Unfortunately, the same cannot be said with regard to the array of financial tools upon which the burgeoning commercial space industry is utilizing to scale. The commoditization of goods and services derived

[31] Office of Legacy Management (2023). A Brief History of the Department of Energy. DoE.
[32] Perrow, C. (2006). "The Disaster after 9/11: The Department of Homeland Security and the Intelligence Reorganization." Homeland Security Affairs.

from space technology requires the attention of Wall Street, facilitated by a credible economic model that is backed by industrial policy and national strategy. The objective here is to normalize the new space economy in a manner that sustains its growth and realizes future contribution to our gross domestic product. Sustained U.S. leadership requires a non-government center for the economic development and commoditization of space that objectively tracks and identifies commodities that are ready for the market.

De-SPAC strategies - The boutique SPAC transaction approach to scaling new space companies through an initial public offering has had marginal success at best, according to the participants and body of relevant analytic research. At present, the true value of many space companies is so undervalued beyond their real property assets that it is perilous to believe they will survive without intervention according to many participants. The only means to effectively 'de-SPAC' a company is for private investors to buy it out. In the absence of incentives, this may not likely occur, leading to a potential winnowing of unique capabilities that contribute to resilience.

Debt Financing - Beginning in FY24, the Office of Strategic Capital (OSC) will enter the field of financial securities by offering government-backed debt financing and other investment incentives that encourage continued private investment in technologies of importance to national security. Debt financing is an excellent option for scaling production of proven capabilities such as satellites, spacecraft and launch vehicles. At present, commercial companies can only utilize subsequent venture capital series raises which further dilutes ownership in these firms. As previous SSIB Reports have emphasized, only a small number of space companies currently leverage debt financing.

Commoditizing is Key - Properly introducing space commodities into today's financial markets is paramount to establishing a path to continuous capital access and growth. Early commoditization of remote sensing data, imagery, launch, debris removal, propellant, semiconductors, pharmaceuticals and other items produced in and for space will have a profound impact on the scaling, financing, insuring and interoperable standardization of these goods and services in the future.[33] The government benefits in cost savings, de-risking and continuity from procuring these goods and services as functionally defined commodities at fair market prices based upon competitive rather than speculative conditions. "Space commodities" include the financial derivatives, indices and other financial instruments that trade as commodities and would serve to transfer risk and match supply and demand curves for the space economy to become sustainable using market mechanisms familiar to institutional and other long-term investors. Establishing the Space Commodities Exchange under U.S. regulatory oversight, where trades are denominated in U.S. dollars will strengthen the U.S. national security and projection of U.S. economic strength in and for the space economy. As amongst Exchange members, the rules for the Space Commodities Exchange will accelerate filling gaps in the currently uncertain arena of commercial space law.

[33] The design for the Space Commodities Exchange presented in this Report reflects research and proposals presented in: Cahan, B., Marboe, I. & Roedel, H. (2016). Outer Frontiers of Banking: Financing Space Explorers and Safeguarding Terrestrial Finance. New Space; Cahan, B., Pittman, B, Cooper, S. & Cumbers, J. (2018). Space Commodities Futures Trading Exchange: Adapting Terrestrial Market Mechanisms to Grow a Sustainable Space Economy. New Space; Cahan, B. & Locke, T. (2018). Space Commodities in Service of National Security. 2018 AIAA SPACE and Astronautics Forum and Exposition; Cahan, B. & Sadat, M.(2021). Space Policies for the New Space Age: Competing on the Final Economic Frontier. NewSpace NM (now NewSpace Nexus).

TEAMING WITH GLOBAL PARTNERS

Global Relationships based upon Trust - One of the United States' most enduring advantages is its long-standing relationship with allies, coalitions, and partners. As the world grows smaller through advances in transportation, communications and trade; the interdependencies between nation states become ever more evident. The strength of these relationships has been tested during times of crises, and more recently by the rise in global competition from near peers and adversaries alike. Despite periodic stresses and strains, these partnerships endure because they were founded on mutual trust. Much of what we enjoy today was secured at tremendous cost in the form of national treasure lost during regional and global conflicts. When we team together shoulder-to-shoulder, big problems grow small and big bullies are deterred. Securing an enduring peace at this most vulnerable time period requires us to work collectively rather than individually to preserve and defend our common interests.

By Rule rather than by Exception - The terms and conditions of these enduring partnerships must be able to evolve and grow where appropriate to retain relevance and reinforce trust. One of the most profound observations to emerge from the Ukraine conflict is that commercially-sourced technology has contributed significantly in countering the Russian invasion. While some policies have changed, many were simply waived by exception rather than by rule. As we confront new challenges that require strengthening of our collective security, we must reverse this policy stance to scale these capabilities and more effectively contribute to a collective deterrence.

AUKUS Advanced Capabilities Pillar - One of the best examples of evolving policy is the trilateral agreement recently signed between Australia, the United Kingdom and the United States known as AUKUS. This agreement not only allows Australia access to nuclear submarine technology, but it also opens the door for increased collaboration in areas of technological innovation. AUKUS is a reaffirmation of the foundational trust between partners and a catalyst for properly managing the classification and access to warfighting capabilities that improve interoperability.

"Accelerating technological advances will deliver the operational advantages necessary to defeat current and future threats across the battlespace."

- UK GENERAL ROB MAGOWAN, 2023[34]

The Advanced Capabilities Pillar (also known as Pillar 2) represents a revolutionary approach to trilaterally develop and provide joint advanced military capabilities across many technological areas including hypersonics, quantum, undersea, cyber, electronic warfare and space.[35] Under this agreement, AUKUS partners agree to collaborate on accelerated defense innovation activities that better integrate commercial technology.

[34] DoD (2023). AUKUS Partners Demonstrate Advanced Capabilities Trial. U.S. Department of Defense.
[35] Christianson, J. et al. (2023) AUKUS Pillar Two: Advancing the Capabilities of the United States, United Kingdom, and Australia. CSIS.

ESTABLISHING TRUSTED SUPPLY CHAINS

Supply Chain Provenance - As the United States positions itself for long-term global competition, it is essential that we continue to recognize the value of strong global partnerships and the strength of common supply chains that support our collective security. In fact, it is so important to our shared economic prosperity and collective security that we decided to lead this year's SSIB Report with the results of the Global Partnerships Workshop, held in Monterey in June of 2023.

MOTIVATIONS

Continued Policy Momentum - The National Space Council met in September of 2022,[36] and the National Space Council User's Advisory Group met in February of 2023.[37] The Administration subsequently released a new National Security Strategy[38] which set forth the following objectives:

> Space exploration and use benefits humanity, from creating economic opportunities to developing new technologies and enabling climate surveillance. America will maintain our position as the world's leader in space and work alongside the international community to ensure the domain's sustainability, safety, stability, and security. We must lead in updating outer space governance, establishing a space traffic coordination system and charting a path for future space norms and arms control. Working with allies and partners, we will develop policies and regulations that enable the burgeoning U.S. commercial space sector to compete internationally. We will enhance the resilience of U.S. space systems that we rely on for critical national and homeland security functions. These efforts aim to protect U.S. interests in space, avoid destabilizing arms races, and responsibly steward the space environment.[39]

LEO Strategy - The Administration also released its National Low Earth Orbit Research and Development Strategy[40] which championed many aspects of space development recommended by prior SSIB reports, including strong support for uncrewed, intermittently crewed, permanently crewed commercial LEO destinations, emphasis on reusability, diverse market demand, infrastructure, manufacturing in space, and growth of the U.S. space industry, including the creation of good-paying jobs. The strategy seeks to advance public-private investment in advanced technologies and late-state prototyping including: on-orbit sample handling capabilities, in-space analysis and instrumentation, high bandwidth communications, in-space data processing and storage, robotics, human-machine interfaces, electrical power generation and storage. The strategy seeks to involve previously uninvolved sectors of industry and promote market opportunities and stimulate STEM education workforce development. The strategy advanced two ideas from previous SSIB reports: a STEM ROTC program to build technical capacity, and settlement within the solar system as a national goal.

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[36] NASA (2022). NASA Hosts National Space Council Meeting, Vice President Chairs Event; White House (2022). Remarks by Vice President Harris At National Space Council Meeting.
[37] NASA (2023). National Space Council Users' Advisory Group; White House (2023). Readout of Vice President Harris' Meeting with Members of the National Space Council's Users' Advisory Group.
[38] White House (2022). National Security Strategy.
[39] Ibid.
[40] White House (2023). National Low Earth Orbit Research and Development Strategy.

U.S. National ISAM Policy and Implementation Plan - The Cislunar strategy was followed by a U.S. national policy and implementation plan[41] for In-Space Servicing Assembly and Manufacturing[42] (ISAM). ISAM is that suite of capabilities used on-orbit, on the surface of celestial bodies and in transit between these regimes which includes repairing and refueling spacecraft, building structures, and fabricating components in space as needs arise. The policy and strategy notes that "ISAM capabilities are on the brink of opening new possibilities for U.S. commercial industry and American workers to build, repair, and transport objects in space" and that these could allow global space operators to increase satellite lifetimes; move, tug, or deorbit satellites to avoid debris or to perform end-of-life maneuvers; inspect satellites for damage; maintain, refuel, and upgrade existing satellites; and build and operate larger, more complex systems in space that do not need to be designed to withstand the severe launch environment. The implementation plan includes the identification of high-priority future government missions and architectures enabled or enhanced by ISAM, prioritization of basic and applied ISAM research, to identify gaps in space & ground test facilities and facilitate commercial and academic access. The ISAM implementation plan also asks IARPA and ODNI to work on ISAM related autonomy and AI, as well as energy storage for high-power, high-energy or pulsed power. Most importantly the strategy recognizes the lack of a consistent demand signal to the private sector on government ISAM needs, and seeks to develop an approach to purchase commercial in-space propellant services and infrastructures that includes DoD, DoT, and NASA, and for the USG to adopt commercially-developed modular infrastructures.

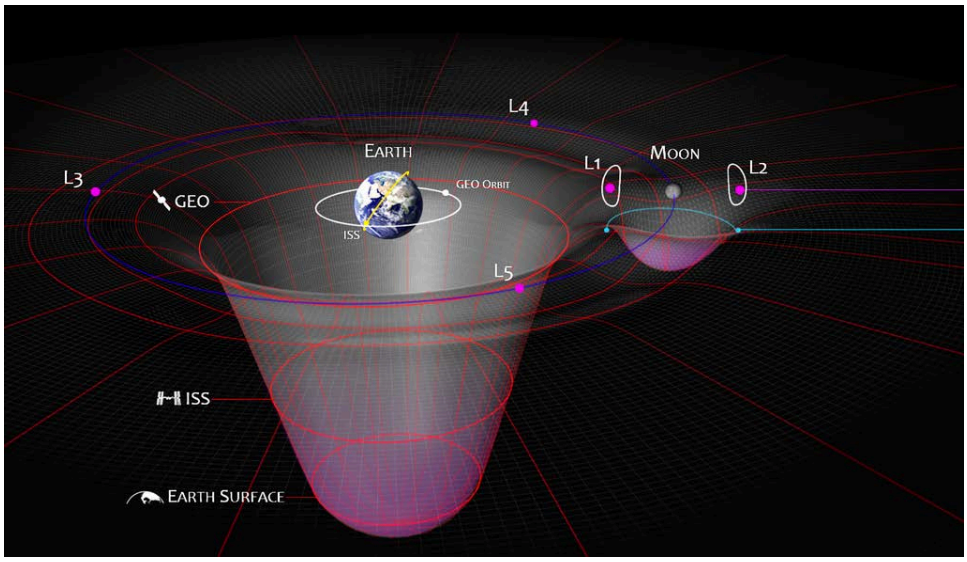

Figure 9. Three-dimensional depiction of Cislunar space. As the Moon revolves around the Earth, the Lagrange points keep the same orientation with respect to the Earth and the Moon. Not drawn to scale. (Credit: NASA)

The First Cislunar Strategy - The Administration took a major step by issuing our first U.S. National Cislunar Strategy[43] which articulated a "vision of responsible, peaceful, and sustainable exploration and use of Cislunar space, including the Moon" and "R&D enable responsible and sustainable space activities, enable economic development, and promote peaceful uses of space to the benefit of all." The

[41] White House (2022). National ISAM Implementation Plan.
[42] White House (2022). In-space Servicing, Assembly & Manufacturing National Strategy.
[43] White House (2022). National Cislunar Science & Technology Strategy.

Strategy prioritizes R&D to enable long-term growth in Cislunar Space, international S&T cooperation, extending space situational awareness, communications, and PNT into Cislunar space, using scalable and interoperable approaches. The strategy also explicitly supported Lunar resource assessments, demonstration of capabilities for materials sourced from the Moon and other celestial bodies, including "manufacturing of components from in-situ materials" and "collaborations with private entities to enable capabilities for large-scale ISRU and advanced manufacturing on the Moon." The strategy prioritized refuelable Lunar landers, environmental control and life support, Lunar surface power systems, mobile and dust-resistant spacesuits, surface mobility in extreme environments, sustainable habitats, and the use of Lunar materials.

DoD's First Commercial Space Integration Strategy - Deputy Secretary of Defense Katheen Hicks announced the Department's first commercial space integration strategy in September 2023 in order to drive integration and ensure the availability of commercial space solutions during competition, crisis and conflict.[44] Under this strategy, DoD seeks to leverage rapidly emerging and unique commercial capabilities such as in-space servicing, refueling and space domain awareness.

Figure 10. Preventing an asteroid impact with Earth and avoiding a catastrophic natural disaster poses a complex global problem that requires a multidisciplinary approach and multinational cooperation. (Credit: NASA)[45]

Planetary Defense Progress - The Space Priorities Framework stated: "The United States will lead, in cooperation with commercial industry and international allies and partners, in efforts to enhance warning of and mitigation against potential near-Earth object impacts." Toward that end, the White House also released an updated *National Preparedness Strategy For Near-Earth Object Hazards And Planetary Defense*, containing taskings for both NASA and DoD[46] and for which NASA released its own implementing strategy and action plan.[47]

[44] Erwin, S. (2023). DoD developing strategy to tap commercial space market. SpaceNews.
[45] NASA (2023). Planetary Defense at NASA.
[46] White House (2023). National Preparedness Strategy & Action Plan For Near-Earth Object Hazards And Planetary Defense.
[47] NASA (2023). NASA Planetary Defense Strategy and Action Plan.

The White House has continued to push for the creation of enduring strategic advantage via the promotion of commercial space and an in-space industrial base. Commercial space has been a key topic for the National Space Council Advisory Group.[48] The White House also sought inputs and is in the process of establishing guidance for the regulation of novel space activities,[49] and to develop a plan to assign regulatory authorities for 'new' space activities.[50] Moreover, the White House has also sought to fund these initiatives, with the President's Budget Request for NASA at $27.2B[51] and $30B for the USSF.[52]

"Our robust and growing team of Partners includes commercial, interagency, and academic organizations. Together these Partners develop and deliver greater military space power that deters aggression and supports space domain stability."

- GEN JAMES DICKINSON, Commander USSPACECOM[53]

Defense Policy & Strategy - DoD also made significant advances in policy and strategy. At the OSD level, the DoD released its new Space Policy Directive 3100.10[54] and updated its Tenets of Responsible Behavior in Space.[55] The updated DoD Space Policy directive codified the following priorities:

a. Recognize space as a priority domain of national military power that underpins multidomain joint and combined military operations to advance national security.
b. Strengthen the safety, security, stability, sustainability, and accessibility of the space domain.
c. Preserve access to and freedom to operate in the space domain.
d. Protect and defend the use of space for U.S. national security purposes, the U.S. economy, and allies and partners of the United States.
e. Conduct operations in, from, and to space, and deliver advanced space capabilities to deter conflict and, if deterrence fails, to counter and defeat aggression.
f. Promote long-term sustainability of the space environment; cooperate with like-minded international partners to establish, demonstrate, and uphold norms of safe and responsible behavior; and cooperate with other U.S. Government departments and agencies to act as a good steward of the domain.
g. Enhance DoD and Intelligence Community (IC) partnership to increase unity of effort and the effectiveness of space operations and space-related activities.
h. Strengthen space-related alliances and build new partnerships that provide a durable strategic advantage for the United States, and its allies and partners.
i. Leverage and promote a thriving domestic civil and commercial space industry, including expanding and increasing emphasis on innovative and emerging commercial space capabilities.
j. Transform the DoD space enterprise to adapt to rapid changes in the strategic environment.

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[48] Foust, J. (2023). Commercial space a key topic for National Space Council advisory group. SpaceNews.
[49] Foust, J. (2022). White House requests proposals for regulating novel commercial space activities. SpaceNews.
[50] Hitchens, T. (2023). White House nears plan to assign regulatory authorities for 'new' space activities. Breaking Defense.
[51] NASA (2023). President's Fiscal Year 2024 Budget Strengthens NASA, Space Economy.; Dreier (2023). NASA's 2024 budget proposal is pretty good, but it faces political headwinds. Planetary Society.
[52] Erwin, S. (2023). U.S. Space Force budget hits $30 billion in 2024 proposal. SpaceNews.
[53] Dickinson, J. (2023). Fiscal Year 2024 Priorities and Posture of United States Space Command. Senate.gov.
[54] DoD (2022). DoD Directive 3100.10 Space Policy.
[55] DoD (2023). Tenets of Responsible Behavior in Space. USSPACECOM.

USSPACECOM progress - USSPACECOM declared that it reached full operational capability (FOC) in 2023.[56] The U.S. Space Command has made significant statements,[57] testimony,[58] and associated OpEds[59] recognizing the importance of securing the space economy. It also established a Commercial Integration Cell (CIC) enabling operational and technology exchange between operators at the Combined Space Operations Center (CSpOC) and commercial satellite owner operator partners for the purpose of real-time and near real-time information flow during daily routine operations. In addition, the CIC enables rapid, informed response to critical unplanned space events or other activities in and through space to improve Space Domain Awareness (SDA).

"Secure our Nation's Interests In, From, and To Space."

- SPACE FORCE MISSION STATEMENT[60]

Space Force Policy Progress - The U.S. Space Force (USSF) also made major upgrades to its policy and strategy. As the Space Force reached three years old and now has its second Chief of Space Operations (CSO), it made a number of changes. Building on its Spacepower Capstone Document, the Space Force also released foundational doctrine on planning, sustainment, intelligence, and operations.[61] It also released a Guardian Spirit Handbook.[62] CSO#2 released a barrage of C-Notes including Three lines of efforts: Fielding Combat-Ready Forces, Amplifying the Guardian Spirit, and Partnering to Win.[63] CSO#2 also set forth 'competitive endurance' a theory of success which seeks to avoid operational surprise; deny first-mover advantage, and engage in responsible counterspace campaigning.[64] A forthcoming Commercial Strategy has been announced.[65] The Space Force is seeking to create a force purpose-built for strategic competition.[66] Both the USSF and USSPACECOM collaborated to create the U.S. Space Force Component to U.S. Space Command, known as the Space Forces – Space (S4S) which will serve as the Space Force organization directly supporting USSPACECOM mission requirements. The USSF also added additional Space Force Components for Europe and Africa. Finally, the Space Force also updated its mission statement to reflect this broader mandate, "Secure our Nation's Interests In, From, and To Space."[67]

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[56] Easley, M. (2023). Spacecom to reach full operational capability by end of year, commander says. DefenseScoop.
[57] USSPACECOM (2023). USSPACECOM deputy commander: how security ensures sustainability.
[58] Dickinson, J. (2022). Fiscal Year 2023 Priorities and Posture of United States Space Command. Senate.gov.
[59] Shaw, J. (2023). Welcome to the Third Space Age. SpaceNews.
[60] Space Force (2023). Saltzman highlights new Space Force mission statement and building a purpose-built service for great power competition.
[61] USSF (2023). STARCOM Publishes Foundational Doctrine on Intelligence, Operations; USSF (2022). STARCOM Publishes Foundational Doctrine on Sustainment; USSF (2022). STARCOM Publishes Foundational Doctrine on Personnel; USSF (2022). STARCOM Publishes Foundational Doctrine on Space Planning; USSF (2023). STARCOM Digital Library.
[62] USSF (2023). Guardian Spirit: Space Force Handbook 1-1.
[63] Hitchens, T. (2023). Space Force chief outlines 3-part 'competitive endurance' theory aimed at 'space superiority'; Breaking Defense.; Erwin, S. (2023). U.S. Space Force game plan: Compete with China, prevent shooting war in orbit. Space News; CSIS (2023). Theory of Success: A Conversation with General Saltzman; Saltzman, C. (2023). Guardians in the Fight. AFA Warfare Symposium Keynote; Garretson, P. (2023). Episode 40. Gen. Chance Saltzman: Competitive Endurance, Proposing a 'Theory of Success' for the Space Domain. Space Strategy Podcast.
[64] USSF (2023). CSO releases Lines of Effort.
[65] Erwin, S. (2023). Space Force to release guidelines for the use of commercial satellite services. SpaceNews.
[66] Saltzman, C. (2023). Watch, Read: CSO Saltzman on 'The State of the Space Force'. Air & Space Forces.
[67] Space Force (2023). Saltzman highlights new Space Force mission statement and building a purpose-built service for great power competition.

Faster Acquisition - Undersecretary of the Air Force for Space Acquisition Hon. Frank Calvelli outlined a new space acquisition philosophy, priorities, tenets[68] emphasizing: building smaller satellites, smaller ground systems, and minimizing non-recurring engineering; getting the acquisition strategy correct; enabling teamwork between contracting officer and program manager; awarding executable contracts; maintaining program stability; avoiding special access program and over classifying; delivering ground before launch; holding industry accountable for results; and execution: delivering capabilities that work, and delivering them on schedule and on cost.

"In order to reshape the architecture as fast as possible, I believe we need to drive satellite acquisition contracts to take less than three years from contract start to launch."

- HONORABLE FRANK CAVELLI, 2023[69]

CHALLENGES

Temporary Federal Spending Authorizations - Last year's SSIB publication referenced a Government Accounting Office (GAO) report citing that the U.S. Government had spent 3.4 years (34%) of the previous decade (2012 to 2022) operating under Continuing Resolutions (CR) or temporary spending bills.[70] This trend was sustained in Fiscal Year 2023 (114 days) and, as of this publication date, is already in the fourth CR period for Fiscal Year 2024. CR authority not only results in costly impacts to defense acquisition programs of record, but also contributes to the 'Valley of Death' for innovative commercial companies who must wait to start or continue on-going business with the U.S. Government.

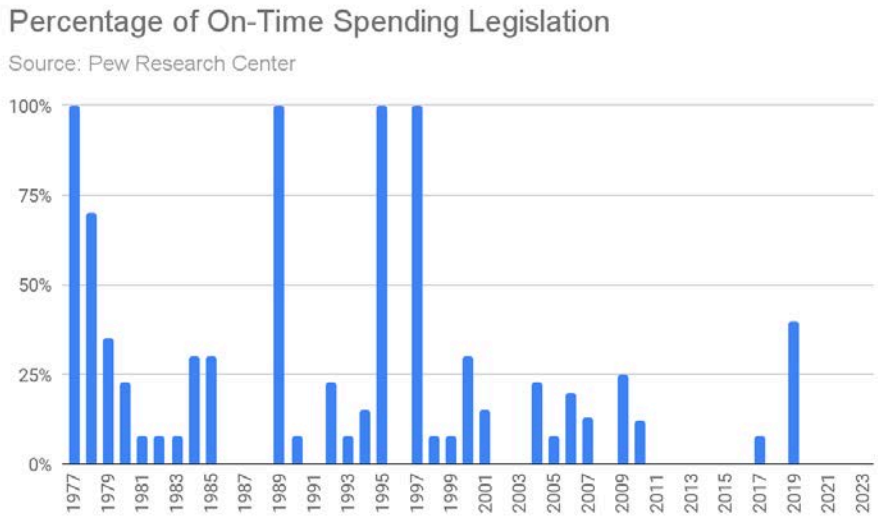

Figure 11. Percentage of stand-alone appropriations bills passed before the 1 October deadline each fiscal year (Credit: Pew Research Center)[71]

[68] Space Force (2022). DAF outlines space acquisition philosophy, priorities, tenets.; Space Force (2023). Space Force "Simple Formula to Go Fast in Space Acquisition".
[69] Hitchens, T. (2023). Space acquisition office weighs mission priorities in case satellites go down. Breaking Defense.
[70] Arkin, J. (2022). What is a Continuing Resolution and How Does It Impact Government Operations? GAO.
[71] Desilver, D. (2023). Congress has long struggled to pass spending bills on time. Pew Research Center.

Secure and Stable Access to Capital - In a 1940 radio address to the nation, President Franklin Roosevelt characterized the U.S. industrial base as an 'Arsenal of Democracy' that would help supply our allies in the war effort. Nearly a century later, there is growing recognition that commercial innovation is key to preserving the collective security of the U.S. and its allies in deterring conflict, defending the Homeland and winning if forced to fight. In order to sustain the Arsenal of Democracy, innovative companies must continue to have access to private capital under the most responsible circumstances. The recent contraction of the economy and insolvency of Silicon Valley Bank[72] revealed the fragility in relying on our existing financial system for nascent parts of the economy such as commercial space. Venture capital gives America its strategic edge. Notably, space and artificial intelligence companies dominated this year's edition of the NatSec 100, an annual ranked list of the top venture-funded defense and dual-use startups published by Silicon Valley Defense Group (SVDG).[73]

Planning, Programming, Budgeting, and Execution (PPBE) Reform - Congress established the Commission on PPBE Reform under Section 1004 of the Fiscal Year 2022 National Defense Authorization Act. The Commission recently published an Interim Report in August, identifying five focus areas: improving PPBE-related relationships between the DoD and Congress; enabling PPBE processes to implement innovation and adaptability at the speed of relevance; aligning budgets to strategy; digitizing PPBE business systems and employing data analytics; and improving the capability of the PPBE programming and budgeting workforce.[74] Reform of the PPBE process is critical to sustaining U.S. competitiveness and rapidly scaling commercial technology like space where the DoD is an early adopter.

> *"The DoD needs a resourcing structure that is innovative and adaptable enough to field cutting edge capabilities to the warfighter quickly while maintaining congressional oversight."*
>
> - HONORABLE ELLEN LORD, 2023[75]

WORKING GROUP BREAKOUTS

The State of the Space Industrial Base 2023 workshops were dispersed across several locations this year with the objective of providing greater opportunity for geographically relevant centers of the commercial space sector to provide input. Workshop locations included: Seattle, WA; Cape Canaveral, FL; Monterey, CA; Silicon Valley, CA; and Albuquerque, NM. Each workshop was organized with specific breakout sessions enabling dialogue between stakeholders from industry, academia and government to address the challenges above and answer the most important question, "Are we making the progress we should be, and if not why not?" Chatham House Rules were observed within the breakout sessions to facilitate a more comprehensive discussion. Specific working group breakouts for SSIB'22 included:

- Global Partnerships
- Launch Services

[72] Gobler, E. (2023). What Happened to Silicon Valley Bank? Investopedia.
[73] SVDG (2023). NATSEC100, 2023 Edition. SVDG.
[74] Commission on Planning, Programming, Budgeting and Execution Reform. (2023). Interim Report. U.S. Senate.
[75] Ibid.

- Hybrid Space Communications
- In-Space Transportation & Logistics
- Next Generation Power & Propulsion
- Remote Sensing & Traffic Management
- Policy & Finance
- Workforce & Science, Technology, Engineering and Math (STEM) Education

KEY ACTIONS & RECOMMENDATIONS

From the above observations and additional inputs from the working groups, participants advocated for or expressed interest in these overarching recommendations for action:

1. **Embrace a Collective North Star Vision for the U.S. and its Global Partners.** The US must create a safe, stable, secure, and sustainable space domain which builds and advances an enduring competitive advantage for the United States and its global partners for economic prosperity and collective security in pursuit of national goals that embrace the peaceful economic development and human settlement of space in a manner that is consistent with our shared values, democratic principles and appreciation for both human rights and the environment.
2. **Accelerate Transition to Dynamic Space Operations.** The U.S. must create capabilities for the conduct of operations which can respond to challenges in the space operating environment in a rapid and agile manner at scale. This includes responsive spacecraft and payload development and integration, responsive space access not only to orbit but to all areas of U.S. interest, sustained maneuver, and the ability to resiliently re-allocate within and across constellations.
1. **A Shift toward Agile Policy Making and Execution**. We are immersed in a Fourth Industrial Revolution highlighted by accelerated change in the advancement of new technologies. Policy and precedent must maintain pace so that the U.S. and its global partners remain leaders in establishing global standards, norms, and practices consistent with U.S. National Policy, strategy, and objectives outlined in the Space Framework. Policy must outpace innovation, or else the U.S. will concede its competitive advantage for the sake of bureaucratic convenience.

2. **Development and Production at Speed and Scale**. Fast following commercial technology to achieve strategic outcomes requires timely, effective, streamlined, flexible, and enabling contracts, procurement approaches, architectures, digital systems engineering practices, funding paradigms, collaborative development efforts, rapid prototyping, concurrent engineering, and active technology demand pull to fully harness and leverage commercial speed, scope, scale, and production capacity to compete economically while contributing to integrated deterrence.

3. **Address Bureaucratic Delay.** The U.S. needs to incentivize private investment in the space economy so that the USG doesn't have to carry the full burden, but bureaucratic delay (including delays in launch and re-entry licenses per FAA Part 450) destroys or drives away private investment and U.S. competitive advantage. Bureaucratic delays in licensing and

permitting are the single most self-defeating--and addressable problem across the space enterprise.

4. **Sustained Funding for Programs that Leverage Commercial Solutions.** Examples include the Space Development Agency Proliferated Warfighting Space Architecture, Artemis, Hybrid Space Architecture, Tactically Responsive Space (TacRS), xGEO and Cislunar Space Domain Awareness partnerships, and many others.
5. **Protection of Space Commerce.** A continuum of conflict from competitive, thru crisis, and conflict, exists today where space systems, networks, ground stations and infrastructure are all experiencing cyber attacks or are at risk of physical damage through the actions of peer competitors and criminal enterprises. Peacetime is 'all the time' which requires protection of commercial capabilities that contribute to the growing space economy. Integrated deterrence begins with the protection of our national interests across all domains including space.
6. **Supply Chain Trust and Resiliency.** A dynamic, robust, diverse, resilient, innovation-driven, and scalable supply chain, industrial base, and entrepreneurial ecosystem are essential to achieve and sustain our national goals and objectives in space.
7. **In order to save the planet, we must get off-planet.** Advancements in space power production, manufacturing, connectivity, and Lunar resource extraction will be foundational to creating and powering the future multi-trillion-dollar space economy. In order to lead, enabling new and evolved strategy, policy, and law, perhaps even treaties, are required. Activities and human presence in space should be driven by an international rules-based order and systems that uphold liberty and prosperity for all humankind.

Figure 12. Secretary of Defense Lloyd J. Austin III, Richard Marles MP, Deputy Prime Minister and Minister of Defence, Australia, and the Right Honourable Grant Shapps, Secretary of State for Defence, United Kingdom met to discuss the Australia-United Kingdom-United States Security Partnership (AUKUS) on the campus of the Defense Innovation Unit. (DoD photo by Chad J. McNeeley)

GLOBAL PARTNERSHIPS

"America is most effective when we work with our allies... If we really want to slow down China's rate of innovation, we need to work with Europe."

- GINA RAIMONDO, Commerce Secretary[76]

BACKGROUND

The global partnerships working group convened for the first time this year with the goal of fostering a nexus of support for future collaboration amongst allies and partners on matters involving the new space economy and collective security. Participants represented civil and military leaders from Australia, Belgium, Denmark, Germany, Italy, Japan, Netherlands, New Zealand, Norway, United Kingdom and the United States; and organizations including Austrade, Breakthrough Initiatives, Elara Nova, Naval Postgraduate School, Silicon Valley Defense Group, USAF, USSF, NATO and the U.S. Space Command.[77] As with other SSIB working groups, this meeting was held under Chatham House Rule, which led to a free, open and sometimes spirited discussion. The motivation for such a meeting stems from two observations: (1) the profound impact of commercial space technology in countering Putin's invasion of Ukraine; and (2) the realization that the challenges posed by competing in space with China are more manageable if like-minded nations work together.

A round table discussion led by Lieutenant General Nina Armagno (USSF)[78] and co-chaired by Major General (ret) Kim Crider and Deanna Ryals (USSF International Affairs), discussion topics covered many areas the working group believed to be ripe for collaboration such as innovation, test, policy, acquisition, trade, science and exploration. Working group topics included:

- Opening the door to doing business (buying and selling commercial solutions) with partners.
- Improving partner access to space capabilities via Direct Commercial Sales (DCS) and Foreign Military Sales (FMS).
- Cultural and policy impediments that need to be resolved to strengthen partnerships.
- Dual-Use Perspective. Facilitating a mindset shift from U.S. programs of record to integrated solutions that integrate commercial partner technologies. What should a future Program of Record look like to be successful?
- Building and growing the global industrial base to meet current and future needs across commercial, civil and national security space including capabilities offered 'as a Service.'

[76] Macias, A. (2021). U.S. needs to work with Europe to slow China's innovation rate, Raimondo says. CNBC.
[77] Additional guests represented the National Space Council, the Office of Science and Technology Policy, the Department of Commerce, the National Aeronautics and Space Administration, the Office of the Undersecretary of Defense for Space Policy, the Defense Intelligence Agency, the Secretary of the Air Force International Affairs Office and the Department of State.
[78] Lt Gen Nina Armagno retired from the USSF with 32 years of exceptional service in late 2023.

- Enabling human capital to build stronger bonds such as the Foreign Area Officer (FAO) program, State Partnership Program (SPP), and Space Reservist integration as means of building and growing trust through enduring relationships with allies and global partners.

Areas of current collaboration discussed included professional military education, exercises, and on-going efforts to update the International Traffic in Arms Regulations (ITAR) that restrict the offshore movement of launch vehicles and remote sensing satellites.

As detailed in our SSIB '22 report, commercial satellite imagery enabled the world to witness Russia's military buildup over the weeks preceding the invasion, while commercial satellite communications denied Russia's ability to silence President Zelenskyy and his people's ability to use personal smartphones to communicate the atrocities committed against the Ukrainian people.[79] Advanced algorithmics employing computer vision and artificial intelligence provide real-time analysis of bomb damage and war crimes, such as the targeted destruction of schools, hospitals, churches and residential areas. What was unprecedented is that all of these capabilities were unclassified and commercially available to all across the global community. Commercial space technology not only provides early indications and warning of potential conflict, but it has proven to be resilient and easy to use with very little training time in combat. Technology is an instrument of national power that, when used effectively at scale, may significantly contribute to the deterrence of future conflict.

"Cooperation with our allies and partners is essential to promoting responsible space operations and protecting our interests in the domain."

- JOHN PLUMB, Asst. Secretary of Defense for Space Policy [80]

CURRENT STATE

14+ Allies have national military space capabilities - To integrate and make full use of this potential synergy will require innovations in U.S. Policy. Nevertheless, with few exceptions space is insufficiently recognized as a potential security cooperation opportunity.

Rapid diffusion - Allies are witnessing a rapid, massive change where progress in global development has resulted in a global talent pool and rapid global diffusion of space technical know-how.

China's rapid advancement - Allies evidenced both awareness and concern regarding the PRC's advances in space, not only in the pace of the Chinese program, but also its depth and breadth.

New relevance of commercial to national security - The rapid growth of the commercial space industry globally, combined with the demonstrated value of commercial satellite imagery supporting Ukraine as well as the demonstrated resilience of Starlink to withstand electronic warfare and cyber-hacks, has demonstrated the space sector's increasing relevance to national security.

The commercial sector is an essential piece to collective security - Innovation is faster, sharing is broader, and capital investment is growing. Access to and rapid incorporation of latest technologies, and architectures are critical to building resiliency in space.

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[79] Olson et al (2022). State of the Space Industrial Base 2022 Report. DIU.
[80] Vergun, D. (2023). More Nations Meet to Address Space Security. DoD News.

Supply chain risks - U.S. and Allied strategy on defense industry (both domestic and foreign-based) is to mitigate or even preclude future supply chain issues regarding materials used in building space or space-related systems and components. There are significant concerns regarding our collective production capacity (US/Allies/partners), commercial production capacity, and ability to source both the necessary quality and quantity. One potential tool at the U.S.' disposal are the broad authorities within the Defense Production Act, and Title III specifically to attract new commercial partners and mitigate the effects of industry consolidation on competition.[81]

Incoherent Implementation - Workshop participants perceived the current U.S. global partnership activity as incoherent. It lacks an enduring strategy to translate policy into impactful activities. At present, many feel that progress is driven by personality--rather than by broad adoption of policy. There is a greater need for top-down direction and mid-level adherence to policy executed at the implementation level. Space policies which seek to advance global partnerships will require cultural buy-in within the systems which support and implement it. *This buy-in has yet to be created*. The current suite of available means include a greater role for education, liaison and exchange officers, Space Situational Awareness Agreements, and Global Sentinel (USSPACECOM's premier security cooperation effort).[82]

Figure 13. Participants of the first State of the Space Industrial Base Global Partnerships Working Group sponsored by the USSF and DIU at the Naval Postgraduate School in Monterey, CA. (Credit: DIU)

The U.S. has significant (but unmobilized) shaping power - The U.S. remains the largest market, which creates enormous incentives toward which allies and partners could respond--if allowed to do so. To provide perspective, outside of the United States, China, and Russia, the entire rest of the world put up just 13 satellites for defense missions last year."[83] The large market power also enables the U.S. to play a central role in a broader system of establishing standards and practices should it choose to do so.

[81] Edwards, J. (2022). DOD Pilot Program to Use Private Investment to Advance Dual-Use Tech Projects; Halimah Najieb-Locke Quoted. ExecutiveGov.
[82] Leon, E. (2023). Two dozen nations gather for Global Sentinel planning. USSPACECOM.
[83] McDowell, J. (2024). Space Activities in 2023. Planet4589.org.

However, till date and by design, the U.S. made it difficult to share specifications and standards - especially where ITAR-sensitive technologies are concerned.

AUKUS as an example for the Future - The AUKUS trilateral security agreement signed two years ago, followed by the recent bilateral U.S. - Australia Technology Safeguard Agreement (TSA) provides a clear example of the trust that must be fostered between allies and partners. Australia has long wanted to be able to launch U.S. commercial and national security payloads to space; except, in the absence of a TSA, they could not do so under ITAR restrictions. Australia has ideal real-estate for space access, and has significant geographical advantages due to its proximity to the equator and ability to enter many orbital geometries. Thus, there is an enormous commercial opportunity. The internal Australian space market is too nascent to draw in the necessary infrastructure investment to establish spaceports for itself. Now that the TSA is signed, the location advantage provides an enormous opportunity for both U.S. capital and the U.S. market, but also requires a clear demand signal from the U.S. of its desire to launch national security payloads out of Australia.

Narrative Dissonance in Asia, limited resonance & the need to reframe - The U.S. vision and narrative of "strategic competition" does not resonate well with Indo-pacific partners, where China is often their #1 trading partner and close geographic neighbor. Workshop participants suggested the U.S. might achieve greater gains if it reframed its narrative to concentrate on space opportunities and climate change to better resonate with the regional concerns.

Communication with adversaries is essential - Continuous communication, behavior modification tools and incentivization are key to bringing the PRC, Russia and others into the fold. Participants appreciated the need for improved global governance, that most space capabilities are inherently global and, that similar to the oceans, has no 'owner.' They also noted the lack of an equivalent law of the seas, as well as the rising importance of the Moon and potentially critical minerals on the Lunar surface.

The opportunity of new international space cooperation - The U.S. has effectively used the Artemis Accords (led by the Department of State and NASA) as a tool of diplomacy that is aligned with the outer space treaty. There is significant possibility to expand the Artemis Accords membership and to build on its vision with additional cooperative thrusts.

Figure 14. Flags of the 33 nations that have signed the Artemis Accords thus far. (Credit: NASA)[84]

KEY ISSUES & CHALLENGES

The overall assessment is that significant impediments to global partnerships remain. While the U.S. has strongly signaled it wants to increase space cooperation, a diversity of structural and cultural barriers impede the potential value and synergy of allied progress. The key issues highlighted in the 2023 Global Partnerships roundtable include:

[84] NASA. (2023). The Artemis Accords. Retrieved from https://nasa.gov

Threats to allied systems - China, Russia, and other adversaries have focused on developing threats to U.S. and allied space leadership.

Inability to do combined operations - currently, some allies expressed that true combined operations are not possible today, and that there was a need for 'anchoring plans' to get there. Achieving broadly integrated and inclusive combined space operations might signal an inflection point.

Inability to translate policy into fully coherent plans and activity across the enterprise - Despite an increasing number of policy documents and policymakers articulating the necessity of closer space partnerships, participants noted that the U.S. has not managed to translate this policy into fully coherent, actionable plans across the enterprise. This lack of clarity in implementation and collective planning fails to provide leadership to influence changes in the allied industrial base and thus deter conflict.

"Well guys, we've been sharing the highest classified intelligence information with each other since 1946. Here we are in 2023 ... and we haven't done that in terms of defence kit. So we should ask the question, why not? There is no good reason. We need to move ahead. I know this will disrupt a number of things that we currently do, but disrupt we must... We don't have any time to wait. The times are urgent."

- HON. KEVIN RUDD, Former Prime Minister & Australian Ambassador to the U.S.[85]

Classification remains a significant barrier - The sharing of classified data at operationally relevant speeds remains a significant problem. Overclassification severely hampers effective communications both with U.S. commercial industry and our most trustworthy allies and partners. The foreign disclosure process is glacially slow. Even documents classified as controlled unclassified information (CUI) are difficult to share. Some of this could potentially be automated to allow the necessary speed and accessibility through 'zero-trust' and Identity Credentialing and Access Management (ICAM)[86] machine-to-machine processes. Former Australian Prime Minister and current Australian Ambassador to the U.S., Kevin Rudd, is adamant that the AUKUS agreement should relieve Australia, the U.K. and the U.S. from many such restrictions including export control. Until such time as this is demonstrated, the alliance is at a significant disadvantage in deterring future conflict.

No clear path for co-funded acquisitions yet exists - an example of the failure to translate policy is the lack of any clear paths for co-funded acquisitions. A successful co-development / co-production effort to evolve from the Technical Cooperation Program (TTCP) has yet to be realized.[87]

Both U.S. and non-U.S. investors need a strong demand signal from the government - To unlock the leverage that both U.S.-based and foreign venture capital investment could provide requires a clear and cohesive demand signal from both U.S. and allied governments which signal their areas of focus and intentions to purchase from the broader allied & partner pool.

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[85] Macias, A. (2021). U.S. needs to work with Europe to slow China's innovation rate, Raimondo says. CNBC.
[86] Cranston, M. (2023). Rudd slams 'crazy' US red tape slowing AUKUS. Financial Review.
[87] The Technical Cooperation Program (TTCP) is a five-nation, defense innovation network that harnesses science and technology in support of the national defense and security of Australia, Canada, New Zealand, the U.K. and the U.S.

"U.S. Only": A lack of clarity in market signal - Some allies expressed a lack of clarity over what "U.S. Only" means in government solicitations for commercial space technology. Does this mean U.S. domiciled, U.S. owned? Is this law, policy or just culture? And who can provide an authoritative answer?

U.S. requirement to have U.S.-owned, U.S.-domiciled companies creates barriers to entry - For example many Australian companies cannot afford the high cost of creating and maintaining U.S. subsidiaries. Moreover, companies have concerns their technology could get 'stuck' in the U.S.. This is leading a reverse 'brain drain' of promising startups -- for example Anduril and shield AI moved to Australia to develop externally and avoid export controls.

ITAR/EAR remains a barrier - While the U.S. might like to make use of partner industrial base and skill set, the current ITAR/EAR creates too much of an impediment to working with allies and partners. U.S. industry cannot fulfill a role as a leader and partner in space because of their perceived requirement to steer clear of potential ITAR/EAR problems, even with close allies and partners.

Defense trade in space capabilities is difficult - The lack of transparency of the DoD acquisition system makes it unnecessarily hard for domestic and even harder for foreign companies to understand.

In 2012, the Pentagon launched the Defense Technology and Trade Initiative (DTTI) with India seeking "an unprecedented joint endeavor that brings sustained leadership focus to the bilateral defense trade relationship, creates opportunities for U.S.-India co-production and co-development." Yet as of 2023--11 years later--there is no co-production or co-development of any space system.[88]

Such calls have not abated, including in the most recent joint statement: "President Biden and Prime Minister Modi set a course to reach new frontiers across all sectors of space cooperation ... President Biden and Prime Minister Modi committed their administrations to promoting policies and adapting regulations that facilitate greater technology sharing, co-development, and co-production opportunities between U.S. and Indian industry, government, and academic institutions."[89]

And "The Ministers reaffirmed their commitment to further deepen the multifaceted defense partnership through wide-ranging dialogues and military exercises of increasing complexity and sophistication, accelerated joint projects initiated under the June 2023 Roadmap for U.S.-India Defense Industrial Cooperation and expanded collaboration in emerging domains, such as space and artificial intelligence...Looking ahead, the Ministers welcomed the progress achieved towards co-production and co-development of defense systems, noting their mutual interest to co-develop and co-produce ground mobility systems as they bring the two countries' respective defense sectors closer together"[90]

The eligibility requirements are not clear. The existing process for international collaboration is excessively slow and needs to accelerate to the pace and speed of relevance.

How do we buy together? - What is the mechanism? There does not seem to be a mechanism for integrated acquisition planning, and the U.S. willingness to collaborate in acquisition, architecture or force design plans with key allies is still limited. How then can allies synchronize policy with technological development?**Design to fielding is too long** - Participants expressed concerns that it is

[88] DoD (2015). Fact Sheet: U.S.-India Defense Relationship. DoD
[89] White House (2023). Joint Statement from the United States and India.
[90] DoD (2023). Joint Statement on the Fifth Annual India-U.S. 2+2 Ministerial Dialogue. DoD

still taking far too long to go from force design to actual systems fielding, and that this impacts allied security and allied participation in security as well.

Sharing tech is cumbersome - Integration and interoperability of space technology remains difficult. Systems that need to be capable of interoperability need to be built for releasability. They need to be built to allow allied and partner industrial collaboration.

Information Sharing & Interoperability built upon specifications and standards - The U.S. to date has not provided the kind of leadership in allied standards for systems, data interoperability or metadata standards. For example, the NATO Space Center[91] ingests data for space domain awareness, but not in the same format. While it is recognized that early adoption of standards can kill innovation, especially in new and rapidly evolving interfaces, standards provide the basis for interoperability, and thus a balance must be struck. Even where standards exist, till date, the U.S. has been less than helpful in sharing such standards and specifications with its allies and partners.

More Barriers to Entry - Other barriers to participation by foreign companies include various certifications such as the Cybersecurity Maturity Model Certification (CMMC) program.[92]

"This is the right time with the right policy makers to make meaningful changes for the better."

- PARTICIPANT, SSIB Global Partnerships Workshop

KEY INFLECTION POINTS

- Ability to plan and execute Combined Space Operations is achieved.
- First Allied-by-Design requirements document with allied standards for communications, data and metadata.
- Creation of combined space industrial base definition authorized by Congress and executed through bilateral agreements.

KEY ACTIONS & RECOMMENDATIONS

U.S. and Allies need to prevent operational surprise, deny first-mover advantage (build resilient architectures), practice responsible counter space campaigning, and share (data, intel) at speed of need. In order to accomplish this, it is necessary to build understanding between the U.S. and allies regarding each other's risk-tolerance and goals, become creative in addressing supply chain issues[93] and prepare flexible and agile policy before conflict breaks out, in order to reflexively and effectively act in unison.

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[91] NATO (2023). NATO Space Centre of Excellence; NATO (2023). Lift-off, NATO Launches New Space Centre of Excellence; Machi, V. (2023). NATO's forthcoming space center for excellence hits key milestone. Defense News.
[92] U.S. DoD CIO (2021). Overview of the CMMC Program.
[93] For example, Russia's invasion of Ukraine affected the supply of precious metals, noble gasses important to both semiconductor supply and spacecraft propulsion (Xenon): The Economist (2023). How rare-gas supply adapted to Russia's war; Athanasiaand, G. & Arcuri, G. (2022). Russia's Invasion of Ukraine Impacts Gas Markets Critical to Chip Production. CSIS; Hong, P. Peterson, E., Kapoor, B. & DeLong, D. (2023). The Crisis in Ukraine Spells More Trouble for Semiconductor Supply. MIT Sloan Management Review.

It is crucial to sync policy with partners from the start for buy-in and threshold; top-down policy needed to direct, streamline, and facilitate acquisition and partnering. The U.S. and allies/partners need to get to an 80% solution that allows for data and capability sharing at unclassified/non-classified level. Revisiting ITAR/EAR and implementing common space data transport standards now will enable this going forward.

Winning the New Space Race Collectively - In this context, winning collectively implies that the United States and its global partners preserve their ability to shape the most desirable space future for all humanity based upon shared values and a strategy that is inclusive rather than exclusive (or dominant) of other nation states, commercial companies or people. An internationally acceptable rules-based order should follow us to the stars.

Figure 15. Secretary Antony J. Blinken (far right) and Australian Prime Minister Anthony Albanes (far left) watch as Australian Ambassador to the U.S. Kevin Rudd (seated left) and U.S. Assistant Secretary for the Bureau of International Security and Nonproliferation C.S. Eliot Kang (seated, right) sign the U.S.-Australia Technology Safeguards Agreement permitting U.S. space launches from Australia. (DoS photo by Chuck Kennedy)

Service International Affairs offices (IAs) are critical - They have long-established expertise in relationship building and defense trade. There is a need to identify what are the contract mechanisms available to promote better synergies and leverage allied and partner industrial bases. There is likewise a need to examine the tradeoffs between exchange officers who function as part of the receiving team, and foreign liaisons who represent the host nation.

Potentially larger roles - While the front-lines of cooperation are often the embassy country teams, the Combatant Command international offices, and dedicated security cooperation organizations like DSCA and SAF/IA, there is likely a roll for organizations such as the Space Acquisition Council which could speak authoritatively about industrial and supply chain needs, and the Defense Innovation Unit whose contracting mechanisms and authorities could allow for a more agile on-ramp of partner commercial capabilities. Similarly, the potential role of the NTIB. There is an overall need to educate the industrial base about the avenues for ally and partner cooperation.

SHORT-TERM PAYOFF

Carefully craft requirements with allies and allied business in mind and then clearly articulate them to each partner will be key to interoperability, force multiplication, and success in space.

Develop targeted list for engagement - With the 14 countries with military space capabilities, the DoD could develop a targeted list of engagements.

Mobilize Foreign Area Officers - The USSF deploys Foreign Area Officers in 82 countries. How can the U.S. connect to gain their expertise of countries' military space capabilities and introductions to the right country PoCs to facilitate cooperation in materiel development, services and joint operations?

MID-TERM PAYOFF

Moving to 'allied-by-design' - If the U.S. is to maximize its potential synergy, a mindset of allied-by-design must expand to deliberately promote specifications and standards to its partners.

Create "Innovation funnels" for allies and partners - It should be possible to build on the strength of allies' strength (from geographic locations, to strategic minerals, to facilities and talent pool). To do this requires a greater understanding of allied and partner industrial bases. This can be achieved through the more conscious use of the diversity of tools across the entire maturity continuum from: Foreign Comparative Test (FCT), Authority to Build Capacity (Title 333 funds),[94] joint ventures, Joint Pitch Days, DIU CSOs, CRADAs and Cost-Sharing Agreements such as through AFRL, grants (such as through AOARD/EOARD).

Capture lessons learned from Ukraine - Ukraine is not the only partner that faces potential aggression. The DoD should capture best practices and lessons learned from Ukraine to apply to future conflicts.

Create deployable capability - This might include replicating the structures (deployment, personnel, ground-link terminals, contracts, authorities) and creating it as a rapidly deployable capability to source and incorporate commercial overhead sensing and satellite communication with experts trained in the 'advise-assist' mission using commercial space capabilities. Since technology changes, it might be valuable to conduct experiments and to train units in such a capability.

LONG-TERM PAYOFF

Reform Export Control regime (ITAR/EAR) and ability to use DPA Title III to leverage allied industrial bases.

[94] DSCA (2023). Section 333 Authority To Build Capacity.

Figure 16. The creation of an internet in space will serve as key infrastructure enabling human and economic expansion into our solar system beginning with the Moon and then Mars. (Source: Aalyria)

HYBRID SPACE COMMUNICATIONS

"Our approach to hybrid architectures affords several benefits including resiliency, cost competition, responsive surge capacity, rapid technology refreshment, increased innovation, improved diversification to industry, and more expedient integration with international partners."

– DEPARTMENT OF THE AIR FORCE, FY24 Posture Statement

BACKGROUND

Since the State of the Space Industrial Base 2022, commercial space communications have accelerated and expanded across orbital levels and planes, increasing their utility in a Hybrid Space Architecture (HSA) and nearly all levels of leadership across the U.S. Government have acknowledged the need for proliferated hybrid communications throughout commercial, civil and national security applications.

CURRENT STATE

Space Development Agency (SDA) - Following a realignment underneath the U.S. Space Force and a name change from their multi-mission National Defense Space Architecture (NDSA) to the Proliferated Warfighter Space Architecture (PWSA), SDA made great strides in their endeavor towards a proliferated LEO constellation with the successful launch of 18 satellites from their Tranche Zero schedule.[95] This great milestone for the DoD's vision of an interconnected warfighter network enables an expedited future launch schedule for Tranche One deliveries completing their 161 satellite constellation over the next 18 months. "Starting in September 2024, we are planning one launch per month for the next year; I'm pretty excited about that," SDA Director Tournear said.[96]

The escalation of hostilities towards commercial infrastructure was evident this past year through a rapid increase in commercial services being impeded, manipulated, and even sabotaged by state and non-state players. From Russian radio frequency jamming attempts on Starlink terminals, to the cyber attack on Viasat satellites, or the Nord Stream underwater pipeline sabotage and a Chinese fishing trawler incident resulting in a Taiwanese communications line being cut, 2022 and 2023 saw commercial companies at the forefront of campaigns to probe commercial infrastructure vulnerabilities. There is no doubt that events such as these will increase in the near term.

Emphasis on allies and partners - The inherently international nature of the internet and space communications has been recognized, most visibly by Joint All-Domain Command and Control (JADC2) being augmented to encompass combined forces in CJADC2.[97]

[95] SDA (2023). Space Development Agency Successfully Launches Tranche 0 Satellites.
[96] Erwin, S. (2023). Space Development Agency's first satellite launch hailed as model. SpaceNews.
[97] Gill, J. (2023). Return of CJADC2: DoD officially moves ahead with 'combined' JADC2 in a rebrand focusing on partners. Breaking Defense.

The Commercial Space Office (COMSO) was stood up by Space Systems Command (SSC), unifying the management and strategy of the SSC Front Door, Commercial Space Marketplace for Innovation and Collaboration Center (COSMIC), SpaceWerx, the new Commercial Augmented Space Reserves (CASR), the Space Domain Awareness marketplace, and the Commercial Satellite Communications Office (CSCO).[98]

KEY ISSUES & CHALLENGES

The key issues highlighted in the 2022 State of the Space Industrial Base report remain:

- **Acquisition and contracting** remain poorly suited to purchasing data as a service. Inadequate funding for project scope and execution of funding within a timely period of performance continue to hamper implementation efforts. New concerns were presented with the SBIR process not aligning with commercial business models.
- Acquiring **Security Clearances, Information Assurance Certification, and Authority To Operate Agreements** are still major obstacles to expansion of the industrial base and to project transition timelines. There are many delivered prototypes that are grossly delayed by burdensome and slow processes for authorization and review.
- **Over classification and lack of exportability** of data are still hampering collaboration with allies and partners.

New challenges identified in the 2023 workshop include:

Government Incentivization Towards Technology Interoperability - the government must encourage companies to adopt open standards for hybrid systems interoperability. Vendors need to be incentivized to collaborate in building modular systems rather than follow the traditional model of proprietary, vertically integrated "one size fits all" fostered by DoD contracting. One vendor reiterated the general commercial consensus that "we don't want the government to set or force standards on us, but we do need you to play matchmaker and referee."

Valley of Death Remains - Despite significant growth in the government prototyping efforts, a valley of death still obstructs transition to programs of record. There are promising signs of government agencies moving towards service procurements with Operations and Maintenance (O&M) money as an alternative to traditional procurement, such as NRO and Space Systems Command Commercial Satellite Communications Office (SSC/CSCO).[99, 100] However these programs are thus far each limited to acquisitions within a narrow domain (imagery for NRO/CSPO, communications for SSC/CSCO) without a comprehensive services program of record.

Too many parallel efforts – Participants noted that further refinement of a cohesive Joint warfighter management for CJADC2 is necessary to better and more fully integrate Joint Service and Combined (international allies, coalition, and partners nations) into a more integrated system-of-systems for global Command and Control and Battle Management. Until better focused, aligned, and integrated, these

[98] Kane, L. (2023). Commercial Space Office Brings Unity of Effort to Industry Collaboration. Space Force.
[99] Hitchens, T. (2021). Space Force Plans Up To $2.3B In COMSATCOM Contracts. Breaking Defense.
[100] Maucione, S. (2022). Space Systems Command using a 'buy first' attitude with procurement. Federal News Network.

efforts are duplicating work and confusing the industrial base.[101, 102, 103, 104, 105] The longer this continues, the harder it will be to combine the resulting networks and architectures. There is a critically important window of opportunity to integrate efforts into a true Joint and Combined/Coalition operating environment.

Figure 17. Achieving a hybrid space architecture begins by integrating new and existing space systems that provide communications, sensing and other services such as precision navigation and timing. (Source: Aalyria)

KEY INFLECTION POINTS

Progress towards some of the key inflection points presented in the 2022 State of the Space Industrial Base has accelerated:

Adoption of hybrid space architecture standards - SDA's optical communications standards continue to be widely adopted and successfully demonstrated by industry.[106] 3GPP has issued a revision to direct to cell phone interoperability guidance for 5G Non Terrestrial Networks (NTN) highlighting the need for better time keeping capability in the cellular networks due to the high latency of 5G in space to ground and data scheduling, however there still exists a significant gap within the ground based telecom industry and the space satellite broadband market.

Long term leadership and funding - As identified at last year's SSIB funding is still lagging despite enthusiastic endorsements from leadership. This would be somewhat mitigated by establishing a centralized authority to align the previously identified parallel efforts.

[101] Erwin, S. (2021). DoD seeks ideas for connecting government and commercial satellites. SpaceNews.
[102] Erwin, S. (2021). Viasat receives $50 million Air Force contract to develop space technology. SpaceNews.
[103] Space Development Agency (2022). SDA Seeks Industry Feedback through DRAFT Solicitation for NExT (National Defense Space Architecture (NDSA) Experimental Testbed).
[104] Hitchens, T. (2020). Space Force To Focus SATCOM Management On JADC2 Needs: EXCLUSIVE. Breaking Defense.
[105] DARPA (2022). Space-Based Adaptive Communications Node (Space-BACN).
[106] Space Development Agency (2020). Space Development Agency Optical Intersatellite Link (OISL) Standard.

End-to-end demonstrations of HSA communications enabling CJADC2, Battle Management, Command, Control, and Communications (BMC3), real time tasking, collection, processing, exploitation, and dissemination tasking, collection, processing, exploitation and dissemination (TCPED) for sensor-to-shooter fires and beyond-line-of-sight tactical data links for situational awareness and shared targeting in a fully integrated hybrid network.

End-to-end demonstrations of data chain-of-custody ensuring that data is complete and has not been corrupted or compromised. This can be partially fulfilled by establishing a universally accepted network trust standard and score similar to Quality of Service (QoS) in the TCP/IP definition. Additionally assigning immutable cryptographic signatures to raw data, with a ledger tracking algorithms and analytics run on that data, provides complete chain-of-custody allowing attribution for both new pricing models and error tracing.

"The Committee supports efforts to leverage commercial space networks to create an "outernet" for future military communications and believes the Space Force should undertake activities to promote interoperability standards and use of commercial ground and cloud architectures to increase the integration of commercial space networks."

– HOUSE ARMED SERVICES COMMITTEE, 2022[107]

One new inflection point towards a successful Hybrid Space Architecture was discovered in the 2023 State of the Space Industrial Base workshop:

Fully operational Free Space Optical Communications as an automated transport layer from satellite to satellite and satellite to ground optical stations. Once the data throughput afforded by optical communications is fully realized, new market trades will be necessary to balance edge compute, storage, data transmission, and power use throughout the extended cloud. The evolution from Radio Frequency (RF) broadcasts to optical multibeam communications will ease licensing and bandwidth restrictions and will reduce beam observability and consequently the potential for interception and exploitation of data.

Discussion of these inflection points also exposed a significant new negative inflection point:

Adversaries creating a Hybrid Space Architecture before U.S. and coalition partners would be a disaster for the free world because a singular global network automated, managed, and controlled by an authoritarian state could severely limit foreign relations and business development (both international and domestic). The global consequences of having absolutely no influence over communications, beyond the tactical warfighting aspects alone, emphatically demonstrates the urgency for appropriate policy and funding to enable the Hybrid Space Architecture.

KEY ACTIONS & RECOMMENDATIONS

The following recommendations reflect the numerous inputs from workshop participants and their best assessment of which agencies are best able to enact the necessary change.

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[107] U.S. Congress (2022) Report to Accompany H.R. 4432. House.gov; House Appropriations (2022). Appropriations Committee Releases Reports for Defense and Legislative Branch Bills, Fiscal Year 2023 Subcommittee Allocations.

SHORT-TERM PAYOFF

Programmatic Funding for Hybrid Space Architecture - The size and scope of the Hybrid Space Architecture requires stable and predictable research, development, test & evaluation (RDT&E) funding across the Future Years Defense Program (FYDP), tied to a Joint coordination office to provide unity of effort. Coordinate with NSA and CYBERCOM to maintain consistent industry best practices across all networks, and regulate defensive cyber operations capabilities within space and ground assets. Advise OSD on supply chain forecasting in coordination with the Space Information Sharing and Analysis Center (ISAC).

Establish a forum to share and integrate HSA with our coalition and NATO partners to ensure that our partners not only keep pace in this endeavor for warfighting coordination but also to exploit their best technologies for the benefit of all. Our major strategic advantage in any forthcoming conflict is the strength of our alliances.

Establish an independent industry consortium to address OuterNet standards, incentivize interoperability, and monitor over-classification issues. The industry consortium should assign a representative to SSC Program Integration Council (PIC). The industry consortium should also have a permanent seat in the HSA Coordination Office.

Increase State Department, Foreign Dignitary Offices, and Commercial Industry involvement to manage commercial acquisition approvals overseas to second and third world nations globally. Our adversaries have been proactive in marketing their communication infrastructures globally, so U.S. State Department attachés should be equally well versed in HSA and the future of global communications to accelerate partners' participation in our mutual open standards.

MID-TERM PAYOFF

Establish OuterNet as an explicit Program of Record to ensure that HSA-related efforts are adequately prioritized and addressed and have a transition path.

Enhance the adoption of commercial innovations into operations by standing up integrated operations/acquisition/test transition teams.

LONG-TERM PAYOFF

Establish an OuterNet Working Capital Fund as an expansion of the CSCO RF Broadband Working Capital Fund.[108] Establish innovation programs to encourage adoption of new technologies into the HSA with ramped incentives for successful transitions.

Conduct roadshows to demonstrate various HSA-enabled capabilities and interoperability, akin to existing industry "plug fests."[109]

[108] Hitchens, T. (2020). DOD Drafts New Acquisition Strategy For Commercial SATCOM. Breaking Defense.
[109] Basler AG (2022). What kind of party is a Plug Fest | Software Development at Basler.

Figure 18. Hall Effect thrusters are the first step toward achieving dynamic space operations (Credit: Astra)

NEXT GENERATION POWER & PROPULSION

"The Earth is the cradle of humanity, but mankind cannot stay in the cradle forever"

-- KONSTANTIN TSIOLKOVSKY

BACKGROUND

Following the seminal inclusion of advanced power and propulsion in the 2022 SSIB, this year continues the trend as a separate and critical component to the continued success in the U.S. space industry. Advanced power and propulsion are seen as a fundamental enabler for future space competencies that demand a significant increase in power demands: on-orbit servicing and manufacturing, dynamic space operations, in-space logistics, and deep space human exploration. Despite the anticipated need, the breadth of prototypes and programs incorporating advanced nuclear power and novel propulsion is limited to date. The working group acknowledged the recent signs of progress on this front, with the convergence of civil/military efforts on nuclear thermal propulsion,[110] but stressed the importance of executing commercially-focused space demonstrations as a means to establish inertia in the early years while exercising the policy and regulatory gates that are currently nebulous for the sector. In contrast, the PRC is rapidly advancing in its own space nuclear power program, with a "Megawatt-class Ultra-small Liquid Metal Cooled Space Nuclear Reactor" recently passing a Ministry of Science and Technology comprehensive performance evaluation.[111]

Emergence of Non-Traditional Power and Propulsion - Outside historical radioisotope thermoelectric generators (RTGs) for deep-space NASA missions, the bulk of space power sourcing centers on photovoltaics. But with the growing demand for increased power on spacecraft,[112] and formalized doctrine rooted in space-maneuver[113] and faster transit in deep space, this axiom is in flux. The apertures for space power and propulsion are expanding to include a dynamic set of approaches: nuclear thermal propulsion, nuclear electric propulsion, fission-based power generation, novel RTG isotopes, and compact fusion. Additionally, space propulsion needs are changing, as are the emerging technologies to meet them. Traditional chemical and electric propulsion propellants such as hydrazine, xenon, and krypton that are hazardous, costly, and originate in geopolitically undesirable regions are being challenged by alternative propellants.[114]

CURRENT STATE

This year witnessed substantial new interest in advanced power and propulsion systems.

[110] DARPA (2023). DARPA, NASA Collaborate on Nuclear Thermal Rocket Engine.
[111] Jones, A. (2022). Chinese megawatt-level space nuclear reactor passes review. SpaceNews.
[112] Speckman, L. et al (2023). State of Play Emerging In-Space Propulsion Technologies Commercial Technologies and New Programs 2023 Q1 Update. Aerospace.
[113] USSF (2020). Space Capstone Publication: Spacepower: Doctrine for Space Forces Spacepower; USSF (2023). Space Doctrine Publication 3-0 Operations; USSF (2022). Space Doctrine Publication 4-0 Sustainment; USSPACECOM (2023). USSPACECOM Outlines Requirements for Sustained Maneuver, 'Dynamic Space Operations',
[114] For example: Dawn (2023). Dawn Aerospace; Benchmark (2023). Benchmark Space Systems; Phase Four (2023). Phase Four; Agile (2023). Agile Space Industries.

Multiple Signs of Progress Across Government for Advanced Power - The USG underwent a 56-year absence in non-radioisotope powered nuclear power programs, starting with the only space-operation nuclear reactor, SNAP-10A, ending with the 2021 nuclear thermal propulsion program Demonstration Rocket for Agile Cislunar Operations (DRACO). Since last year's SSIB report, DARPA and NASA have solidified formal collaboration on the project, establishing a convergence of civil/military efforts for nuclear thermal rockets that can move mass efficiently and faster in the space domain.[115] Beyond the DARPA/NASA collaboration on DRACO, multiple USG initiatives have launched or awarded contracts, to include radioisotope and fusion power solutions under DIU's Nuclear Advanced Propulsion and Power (NAPP) initiative and AFRL's Joint Energy Technology Supplying On-Orbit Nuclear (JETSON) power project aimed at space-based fission power and other novel technologies. These targeted projects signify a cultural shift towards advanced nuclear space power/propulsion with focused lines of effort aimed at maturation and validation via operationally relevant demonstrations. These efforts are not programs of record, but span design concepts to operational demonstrations; they are sufficient to at least enable aerospace and nuclear firms to collaborate on space power applications for the future.

New Developments in Radioisotope Power Systems - There is a rich history of plutonium-based radioisotope power systems (RPS, or sometimes interchangeably called RTGs), where the extended half-life and power density were conducive to deep-space missions.[116] However, there is an expansion of RPS concepts outside plutonium, driven by the desire for higher power densities, shorter mission-life requirements, and Tier-1 National Industrial Security Program Operating Manual (NISPOM) status for reduction in regulatory demands. Within the past year, NASA has issued an OIG radioisotope program report, which included in its recommendations to create an RPS resource allocation and technology development strategy,[117] as well as funded development of an Americium 241 RPS for Lunar initiatives under Artemis.[118] Additionally, the European Space Agency is seriously considering baselining Americium 241 supplied by the UK in RPS devices supporting future Lunar and Mars missions.[119] USAF, AFRL[120] and DIU[122] kicked off programs in the past year focusing on spacecraft missions incorporating higher power density available to the spacecraft subsystems derived from non-plutonium RPS.[123] The diversity of

Figure 19. A Radioisotope Small Spacecraft (Credit: Ultrasafe Nuclear Corporation[121])

[115] DARPA (2023). DARPA, NASA Collaborate on Nuclear Thermal Rocket Engine.
[116] For example, Voyager: Wikipedia (2023). Radioisotope thermoelectric generator.
[117] NASA Office of Inspector General (2023). NASA's Management of Its Radioisotope Power Systems Program (IG-23-010).
[118] NASA (2023). NASA Partners with American Companies on Key Moon, Exploration Tech.
[119] World Nuclear News (2022). NNL to develop americium-powered space batteries: New Nuclear.
[120] Hitchens, T. (2023). AFRL picks 3 contractors for JETSON effort to develop fission powered spacecraft. Breaking Defense.
[121] USNC (2022). Ultra Safe Nuclear Selected to Develop High Delta-V Nuclear Small Spacecraft Prototype.
[122] DIU (2023). Powering the Future of Space Exploration: DIU Launching Next-Generation Nuclear Propulsion and Power.
[123] Erwin, S. (2022). Zeno Power gets $30 million to build radioisotope-powered satellite for U.S. military. SpaceNews.

RPSs is expanding the mission horizons to include not just extended, low-level power sourcing, but higher power military and civil applications and near-Earth missions.

Space Nuclear Power Policy and Oversight Trends - Several key space nuclear power executive policies have been released in recent years, to include SPD-6,[124] NSPM-20,[125] and EO-13972[126] – all with the aim of adjudicating the coordination needed for safe nuclear systems to enhance space exploration and human spaceflight. Now, there is a coordinated effort to codify these executive policies into durable long-term legislation, necessary for establishing clear footing and ground rules for space-nuclear initiatives.

Since the release of the first doctrine for space forces in 2022, the USSF has identified space mobility and logistics as a fundamental core competency.[127] Senior leaders have recognized the need for updated platforms and systems rooted in the doctrine, where dynamic space operations provide opportunity outside the traditional constraints of the space domain, such as on-orbit servicing and extended mission life.[128] Ultimately, the vision of dynamic space operations may be fully realized through advanced power and propulsion technologies.

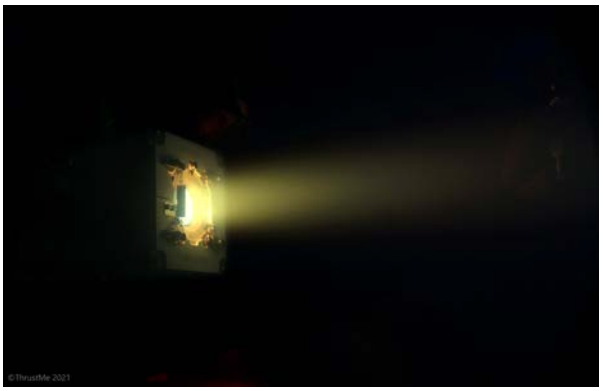

Figure 20. The Norwegian Space Agency's NorSat-TD satellite is fitted with a ThrustMe NPT30-I2 iodine fueled electric propulsion system. (Credit: Thrustme[129])

Increasing Global Interest In SBSP - 2023 saw a significant increase in international interest in Space-Based Solar Power (SBSP). ESA released both a plan and tender.[130] Japan plans a demo.[131] The UK Space Energy Initiative is supported by Saudi Arabia.[132] AFRL has received its payload for its SSPIDR ARACHNE.[133] DARPA began its POWER program.[134] CALTECH succeeded in the first space-to-ground transmission of power.[135] China announced plans to conduct demos on its space station, in LEO and in GEO.[136] As of 2023, the U.S. still had no national-level program.

[124] White House (2020). Memorandum on the National Strategy for Space Nuclear Power and Propulsion (Space Policy Directive-6).
[125] White House (2019). Presidential Memorandum on Launch of Spacecraft Containing Space Nuclear Systems.
[126] White House (2021). Promoting Small Modular Reactors for National Defense and Space Exploration. Federal Register.
[127] USSF (2022). Space Doctrine Note, Operations.
[128] USSPACECOM (2023). Shaw discusses the need for Dynamic Space Operations at the National Security Space Association's 2023 Defense and Industry Space Conference.
[129] Thrustme (2023). ThrustMe NPT30-I2 iodine electric propulsion system launched on board the NorSat-TD satellite.
[130] ESA (2023). SOLARIS activity plan 2023-2025.; ESA (2023). Pre-phase a System Study of a Commercial-scale Space-based Solar Power System (SBSP) for Terrestrial Needs. DevelopmentAid.org; ESA (2023). Pre-Phase A System Study Of A Commercial-Scale Space-Based Solar Power System (SBSP) For Terrestrial Needs. ESA.
[131] Gislam, S. (2023). Japan to demonstrate space solar power by 2025. Industry Europe.
[132] UK Government (2023). Business Secretary in talks with Saudi Arabia to advance commercial collaboration in UK space based solar. Gov.UK.
[133] David, L. (2023). Space Solar Power: Progress Reported in Air Force Demo Program. Leornarddavid.com
[134] DARPA (2022). POWER Aims to Create Revolutionary Power Distribution Network.
[135] Caltech (2023). In a First, Caltech's Space Solar Power Demonstrator Wirelessly Transmits Power in Space.
[136] Jones, A. (2022). China to use space station to test space-based solar power. SpaceNews; Jones, A. (2022). China aims for space-based solar power test in LEO in 2028, GEO in 2030. SpaceNews.

KEY ISSUES AND CHALLENGES

Participants outlined some impediments facing the advanced power and propulsion technologies as consistent themes from previous years: the government's inability to formalize notable, multi-year initiatives to accelerate the industry, while constraining technology approaches for the projects that are formalized. Additionally, the sector faces headwinds due to economic uncertainty and undersupply of talent to mature the industry.

Bridging Interest vs. Demand and Deep Tech Tourism. Space nuclear power is susceptible to the same barriers other novel technologies face: a stark phase delay between keen interest in a technical solution and the availability of an end product or service. Both the government and commercial ventures are awaiting one or more compelling demonstration missions to validate concepts in the space environment or establish heritage prior to investing significant resources, greatly inhibiting the chances of success in the first place. As the likely early adopter and customer, the government sets the tone for market and momentum for subsequent commercial customers. The lack of "big bet" meaningful programs from the government constrains the capital and programmatic incentives to scale beyond the R&D phase.

Existing Advanced Power and Propulsion Acquisitions Stuck in Neutral. For the few existing initiatives that the government is planning, the solicitations are overly prescriptive and not capability-driven. By asserting requirements that are not related to interface or open system architectures, the government diminishes and inhibits participation of small and non-traditional industry players that offer a diverse set of solutions. Moreover, there is insufficient space-nuclear expertise in the government, impacting communication, collaboration, and even awareness of its possible application within the community.

Existing Economic Instabilities and Supply of Workforce Talent. Supply chain disruptions, due to residual COVID pandemic fallout, military conflict, and high demand of critical materials, along with financial uncertainty for future capital and investment, make growth in advanced power and propulsion more tenuous. Additionally, the intersection of physics, engineering, and space expertise makes for a unique talent pool where personnel availability is outpaced by demand.

INFLECTION POINTS

Key Milestones with New Launch Systems - Starship and/or New Glenn reaching orbit, demonstrating heavy lift capability to LEO (~100-ton), would usher dramatic and positive change in launch cost and access to space, perhaps buoyed by the prospect of similar emerging reusable launch systems from China or India. Relaxing the current intense focus on maximal payload performance for minimal mass will enable new business plans and novel concepts of operation in Earth orbit. Successful demos of these new launch capabilities will inform the feasibility of MW-scale nuclear fission reactor space propulsion and power concepts and high-mass space-based solar power (SBSP) beaming projects (space-to-Earth or for supporting in-space mobility), and should accelerate the maturation of supporting large-scale infrastructure capabilities such as orbital refueling and propellant depots (especially for cryogenics) and a breadth of Cislunar space logistics capabilities.

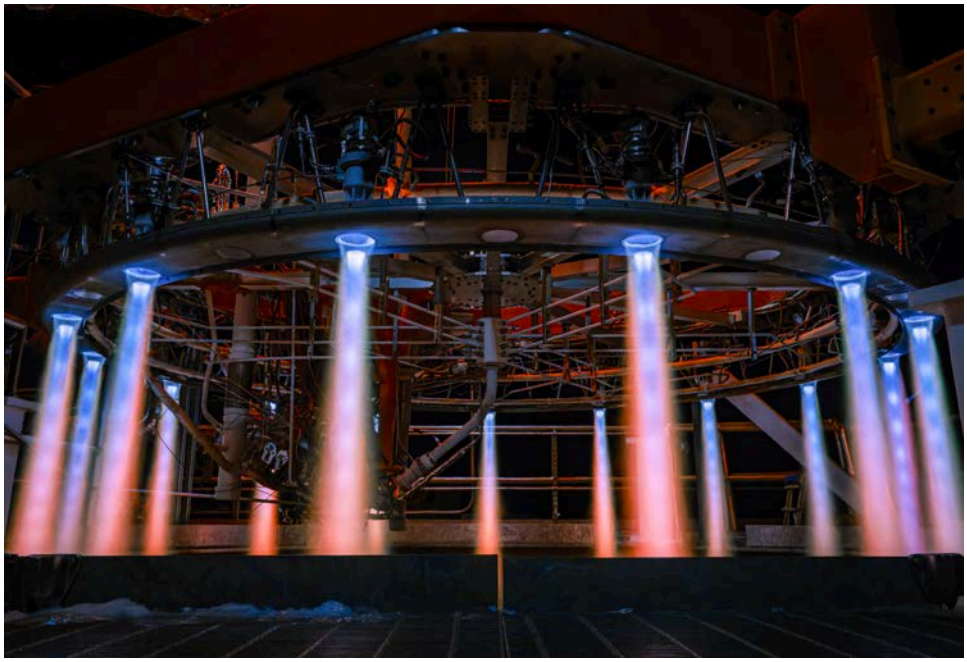

Figure 21. Static test of 15 thrusters that will boost the upper stage of the fully reusable Nova rocket which makes use of the aerospike effect. (Credit: Stoke Space)

Clarification of Long-Term National Strategy for Space - A crisp 'North Star Vision' for the overall U.S. space effort (e.g., eventual settlement of the solar system) would build upon progress made during the past year at the level of national space policy (especially for LEO, Cislunar and Moon-Mars). Within this policy framework, key directives would be issued to allow use of High-Assay Low-Enriched Uranium (HALEU) in space-based nuclear reactors, on how advanced power and propulsion systems integrate into the long-term sustainable Moon-Mars and beyond plan (Artemis), and how related regulatory processes are to be simplified and streamlined.

Successful In-Space Demos of Nuclear Systems - Any commercial in-space demo of a fission or fusion reactor would serve to validate the concept and pave the way for further development and scale-up. The planned DARPA/NASA DRACO mission will be a key demonstration in this mission series. Any explosion on the pad or during ascent could cause a dispersal of radiological materials and would be a major setback to public perception of nuclear power in space.

ACTIONS AND RECOMMENDATIONS

SHORT-TERM PAYOFF

Acquisition and Programmatics for Nuclear Power and Propulsion. Broaden programs and pathways, such as SBIRs/STTRs, so that the rest of the government can easily access space services and data. Complete rollout of a strategic investment fund to accelerate maturity of deep tech for space. More frequent use of open-topic calls that allow flexibility to proposed technical solutions with palatable contract pathways.

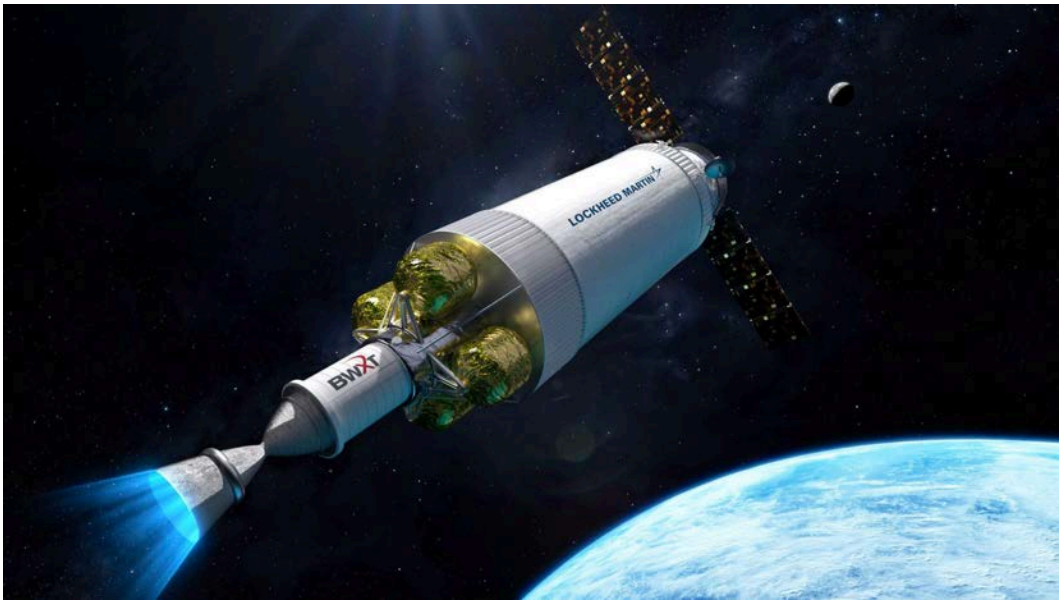

Figure 22. Illustration of the DRACO spacecraft being developed by Lockheed Martin for DARPA that will demonstrate thermal nuclear engine technology. (Credit: Lockheed Martin)

Acquisition Progression of Space Nuclear Policy. Codify the national nuclear strategy into law, stabilizing the long-term guidelines for the community to follow. Finalize and publish the rules and procedures for a commercial nuclear space mission.

Whole-of-Government Investments and Oversight. Develop a strategy and plan to monitor production of critical source materials and resources and ensure they do not fall below minimum levels. Expand the government strategic materials fund to account for needs in the space industry. Publish roadmaps with architectural vision for both government and industry, allowing the sector to compare and contrast needs and solutions. Support expansion and access to critical infrastructure like the National Reactor Innovation Center at the Idaho National Laboratory.[137]

MID-TERM PAYOFF

Establish Strong Demand Signals for Advanced Power and Propulsion to Support GEO and xGEO Demo and Operational Missions - Authorize additional in-space demos of nuclear systems. Encourage formation of industry-led standards working groups for advanced power and propulsion (with government participation). Encourage continued refinement of commercial architectural and technical roadmaps for development, demonstration, validation and scale-up of advanced space-based nuclear power and propulsion systems, including the articulation of specific use cases and missions needing such systems (e.g., fusion-based demo, 100s to 1,000s of kW of space-to-space or space-to-ground beamed power, etc.).

[137] INL NRIC (n.d.). National Reactor Innovation Center: We build advanced nuclear reactors for this century.

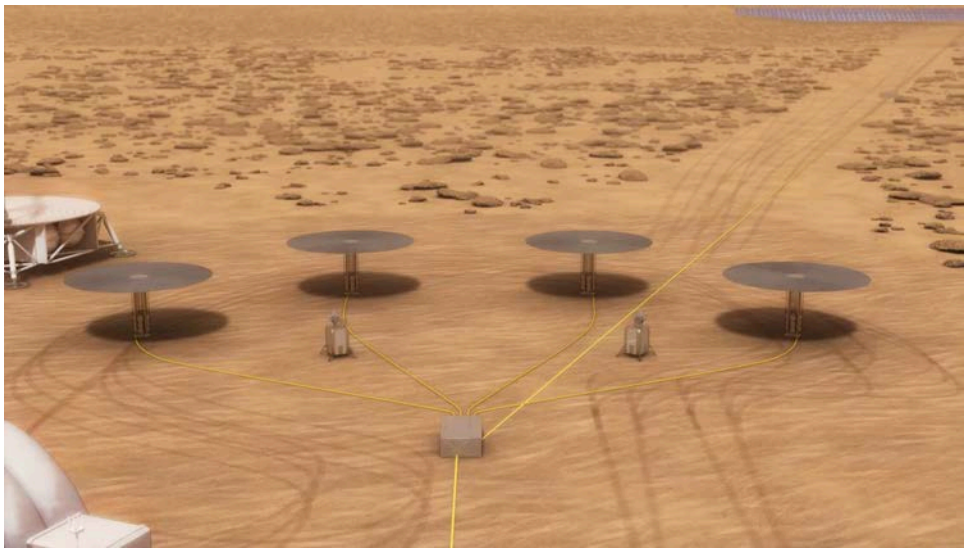

Figure 23. A network of Kilopower reactors, in an artist's concept, could power a Mars outpost without concerns over dust-obscured solar arrays and massive batteries for nighttime use. (Credit: NASA)

Invest in Propulsion Infrastructure (Including Test Infrastructure) as Critical Elements of Space Infrastructure (and Govt-identified national critical infrastructure?) - Designate/clarify available domestic test sites/infrastructure available for commercial use. Expand domestic production capacity for Hydrazine/MMH, NTO, etc. to keep pace with demand. Authorize and incentivize commercial use of HALEU.

Expand and Improve Workforce Development Programs and Supporting Processes - Ensure workforce has needed expertise and experience. Utilize partnerships with academia to help guide students into careers in this domain. Reform personnel and facility clearance processes and increase capacity and reduce approval wait-times (e.g., akin to DARPA Bridges program).

LONG-TERM PAYOFF

Clarify the Long-Term Framework Shaping the Post-ISS Advanced Power and Propulsion Era - Focus on supporting expansion of the Cislunar economy, deindustrializing the Earth and settlement of the solar system. Establish a National Propellant Reserve on-orbit. Streamline related regulations (e.g., nuclear licensing, ITAR, CFIUS, facility issues, security clearances, immigration, etc.).

Leverage the Successes of Proven Space-Related Acquisition Models - Adopt best practices from NASA's public-private CRS, COTS and CLPS programs, those demonstrated by DIU, and other OTA/BAA/IDIQ approaches. Place long-term purchase agreements and, importantly, establish price points for advanced space-based power and propulsion services. Increase the demand signal for such services and related supporting infrastructure, and ensure acquisition authorities at the service-level have access to space-as-a-service solutions enabled by advanced power and propulsion.

Figure 24. Starship launches off the pad under the power of all 33 Raptor engines on the Super Heavy Booster during Test Flight 2 on 18 Nov 2023. (Credit: SpaceX)

COMMERCIAL LAUNCH

"While government (military and civil) space activity remains a significant and growing source of launch demand, the private sector is the fastest-growing segment, amid technological advances and declining costs that have spurred innovation and commercial activity."

- C. DAEHNICK, J. GANG & I. ROZENKOPF, McKinsey & Co.[138]

BACKGROUND

Participants were energetically and actively engaged in providing direct and prolific inputs and recommendations. They noted that the industrial base responsible for putting payloads into space has evolved alongside other critical components within the national security space domain. As the commercial sector responds to government requirements, bringing its agility and innovation to the mission, the fundamental challenges of the marketplace arise as they do elsewhere throughout the economy. Funding, talent, regulation, government management of limited resources and assets inevitably manifest themselves as issues demanding attention, discernment, and difficult decisions. All this is overshadowed by a growing consideration as to how these decisions may prove themselves within a real conflict with a peer adversary. Maybe soon.

Spaceports are increasingly less unique and now more resemble traditional transportation hubs like airports and seaports in need of sustainable and resilient operations. Maritime activities are now integral to the concept of operations of more commercial launch providers. Allocation of limited physical space, whether airspace, sea space, or access to wharfs and berths is now no less challenging than access to spectrum. Complicating these challenges is the recognition that the federal budget is heading into a period of sustained belt-tightening. Yet the adversaries who seek to replace our leadership in space see this as an opportunity.

CURRENT STATE

As the commercial space market grows, so too does the demand on the infrastructure to support that commercial enterprise. One of the key issues and challenges identified in the SSIB'22 Report, is that the current capacity of U.S. space launch complexes is insufficient to meet the growing demand by U.S. commercial, civil and national security launch providers, driving Range of the Future planning and initiatives. "The day of free infrastructure is over." (Frank DiBello SSIB remarks). The Eastern range saw 57 launches in 2022, and projecting up to 92 launches in 2023. The Western range saw 19 launches in 2022, and projecting up to 42 launches in 2023.

International Partnerships - Australia has two commercial spaceports coming online, but they will never have a domestic demand to support the supply, so they are looking for demand signals from allied nations. Australia is not the only nation building up commercial spaceports. The United Kingdom conducted the first launch from European soil in January 2023 from Spaceport Cornwall with Virgin Orbit. The question for us as a nation is, do we want spaceport capabilities outside of the U.S. or not?

[138] Daehnick, C. et al. (2013). Space launch: Are we heading for oversupply or a shortfall?. McKinsey & Co.

Nations building up their spaceports, like Australia, want to be included in the discussions surrounding standard spaceport interfaces. With the establishment of AUKUS and the growing capability and threat of Chinese aggression, and the potential sharing of nuclear submarine technologies, it would seem what before was not on the table is now up for serious consideration.

"If we were going to be able to meet the commercial sector, with the growth that they forecast, we're going to need to make some additional investments in our launch range. We've got a legislative proposal to let them help share some of that cost burden. But I would say we are on a path today and, assuming that we can continue that path, it will be the launch capacity of the nation that will absolutely allow us to keep pace with China."

- GEN. DAVID THOMPSON, Former Vice Chief of Space Operations, 2 May 2023

KEY ISSUES & CHALLENGES

Spaceport Operations and Maintenance Costs - Currently, the DoD is responsible for operating and maintaining the Eastern and Western ranges and cannot accept private funding for much needed infrastructure upgrades. The government spends roughly $500M a year for operations and maintenance costs on spaceports, of which $20M was reimbursable from industry - this cost model is unsustainable for the government. The day of free infrastructure is over - meaning everything has to start with a reasonable basis for charging money; there is precedence for user charges, private companies investing private capital to build up infrastructure, leasing federal land and charging rent. What had been seen as unlikely, too risky, or too unorthodox is now being given consideration. After decades of requests for a major infrastructure overhaul at the federal ranges there now exists a legislative proposal to provide over $1.3 billion to do so.[139] Space Florida has formally requested the IRS Commissioner provide tax exempt status for private activity bonds on spaceports like the tax-exempt status for those bonds on airports and seaports.[140] And now, the Space Force has requested authority to enable them to charge users of the range assets indirect costs to further reduce the subsidized nature of the commercial sector operating on federal ranges.[141]

Limitations extend beyond just a lack of launch pad availability to include a shortage of processing, facilities, and local support infrastructure. The national security space community needs to explore alternatives to address all of these roadblocks.[142]

Spacecraft Processing Facilities - One of the greatest limiting factors remains with spacecraft processing facilities. None are available today; they are all being used for high priority missions supporting the National Reconnaissance Office. Additional contributing factors to limited spacecraft processing facilities are transportation (e.g., limitations with transporting fuel - can't transport hydrazine), and extended processing timelines (i.e., 6 months to process a spacecraft is too long).

[139] Albon, C. (2023). How the Space Force will manage surging launch demand. C4ISRNet.
[140] DiBello, F. (2023). Letter to IRS Commissioner Danny Werfel. Space Florida.
[141] Albon, C. (2023). House lawmakers back Space Force fees for use of launch ranges. C4ISRNet.
[142] Francoeur, N. (2023). Opinion: Space Launch Could Falter...Big Time. Payload Space.

Processing facilities exist all over the country, but preferred operations rely on processing at the launch sites, where they are in short supply. Do we change preferred operations or build more capability at the launch sites?

"The day of free infrastructure is over."

- FRANK DIBELLO, Former CEO Space Florida

Intermodal Spaceport Operations - The Cape Canaveral Spaceport is the busiest and most successful spaceport on the planet. It is immediately adjacent to what is now the busiest cruise port on the planet. Port business models for centuries have been built around providing a location for the transfer of people or cargo from land to water, or the reverse. Then to move out of the way for the next ship to do the same. Where those vessels dock when not in service is its own problem. Port operations and ship positioning are generating challenges beyond the deconfliction of maritime and space traffic.[143]

SpaceX has significant maritime operations for vehicles and fairing recovery requiring a fleet of 6-8 vessels. Those vessels and their operations create impacts on existing Port Canaveral activities requiring adjustments to their planned future developments in support of the existing cruise, cargo and fishing industries. ULA has long used the port to ship vehicles from Alabama, and soon Blue Origin's fleet and operations will arrive creating additional demands on limited wharf and backland capacity. Other commercial launch providers have also approached Port Canaveral regarding maritime components of their concept of operations.[144] These problems will likely arise at any spaceport across the U.S. where the commercial launch providers have maritime recovery operations. Space Florida is conducting a Wharf Study to evaluate existing and potential future assets against known requirements of the commercial sector. Results of the study are expected late in 2023.

Demand Signal for Small Launch Vehicles - Back in 2016, with a building backlog of satellites ready to launch, the number one priority at that time was increasing launch service capacity. The appeal of small inexpensive and easily replaceable satellites, often in large constellations,[145] aligned with the concept of multiple small launch vehicles with minimal launch infrastructure requirements across the country screamed resiliency. The market responded with many new small launch providers raising funds to meet demand. But, as markets do, they are now culling the herd as the landscape changes. SpaceX Transporter launches undercut the price point of viability for most new entrants,[146] and many of the early small vehicle providers are moving to larger vehicles in response to technology and changing markets.[147] If the distributed launch capability of many small launchers across the country is sufficiently desirable for resilience, then additional funding may be required, as the marketplace is moving away from a sustainable business model.

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[143] Berman, D. (2023).Port Canaveral at odds with commercial space companies over dock access. Florida Today.
[144] Cornwell, G. (2023). Space Perspective prepares to introduce new recovery ship as providers compete for land at Port Canaveral. NASASpaceflight.com.
[145] Foust, J. (2020) Small Launch Companies Don't Foresee Price War**.** SpaceNews.
[146] Erwin, S. (2020). SpaceX rideshare program putting downward pressure on prices. SpaceNews.
[147] Erwin, S. (2021). SpaceX's record-setting ridesSpace Perspective prepares to introduce new recovery ship as providers compete for land at Port Canaveral - NASASpaceFlight.comhare mission a challenge for space traffic control. SpaceNews.

Being Patient Without Giving Up The Advantage - China has a centrally managed economy and does not have to play by the rules. A notable example is the solar cell industry: the U.S. was initially on top, but allowed China to employ predatory practices to replace the U.S. as the industry leader.[148]

Striking the regulatory balance - The rapid pace of commercial space launch innovation is frequently at odds with the deliberate and comprehensive regulatory processes that govern the industry. Space launch regulations serve to safeguard the public from known risks discovered through past events. In an effort to encourage innovation and keep pace with their commercial counterparts, regulators have made significant strides to meet industry demand for less prescriptive, tailorable policies. While a positive step towards collaboration, in critical areas, non-prescriptive requirements leave industry guessing at regulatory intent while regulators are left to decipher industry compliance. Finding the balance is a significant challenge that's impeding meaningful progress.[149]

KEY INFLECTION POINTS

- **Two unique rockets successfully launch from the same site on the same day** using largely common infrastructure (e.g. propellant plumbing, launch pad) demonstrating the ability to perform rapid and coordinated launch site logistics, parallel range control operations, and serial day-of-launch checkouts similar to aircraft taxiing and takeoff on a runway.
- **A reusable rocket launches, lands, and relaunches on the same day** demonstrating unprecedented mean-time between flight, routine maintenance reliability, and robust operational procedures.
- **A Shift from Commercial Augmentation to Integration** becomes the operational focus. If we want it, we have to build and sustain it, and the best way to do that is commercially.
- **State and Federal Nexus** is important to the launch sector as the state can do things the federal government cannot do.
- **Global Partnerships realized beyond Paper Agreements** with those nations that are eager to collaborate, but slowed down by regulatory processes and agreements.

KEY ACTIONS & RECOMMENDATIONS

SHORT-TERM PAYOFF

FY24 National Defense Authorization Act allowing the Space Force to charge commercial space companies for indirect costs associated with launch activities and operations (i.e., infrastructure upgrades) at government ranges.

[148] Williams, I. (2023). China is trying to strangle the world's solar panel industry. The Spectator.
[149] This is in reference to the discussion between SpaceX's launch ops team on the automated flight termination system and their manned drone ship operations. A former FAA member talked about tailoring policies and then receiving junk responses from industry, causing his team to work harder to decipher the inputs than they would have had they requested the longer, more clear documentation. Generally though, we see commercial space launch constantly at odds with industry regulation. Regulators aren't staffed to deal with the rapid pace and evolving tech and space launch operators can't afford the time it takes to work through the onerous processes. NOTE: All of this work is completed manually without the benefit of modern software applications enabled with artificial intelligence.

National Spaceport Strategy - This was an action recommended in last year's SSIB report, and is still required. It was suggested at the workshop there is ongoing work, but it is needed immediately.

Normalize real property at the federal spaceports - The federal spaceports should normalize property classifications to establish a single standard process to lease all property on premise. Utilizing a single approach to all property for obtaining commercial lease agreements on a launch installation will create a repeatable, predictable process where all parties are treated equally, while signaling friendly terms to investors and providing competitive options for their commercial customers.

Spaceport Resiliency in a CDOL Environment - Incorporate more participants into tabletop planning for sustained critical operations in a future Contested, Degraded, Operationally Limited (CDOL) environment due to a hot war with a peer adversary, natural disaster or unforeseen event. Assure commodity providers, utilities, and others outside the fence line understand requirements, priorities and have a plan to execute.

MID-TERM PAYOFF

Think outside of the "on-site" processing box - Initiate a comprehensive review of national security, civil, and commercial launch vehicle and spacecraft processing tasks that are currently performed at the spaceport, with the intent of reducing the time, resources, and complexity associated with on-site processing. Identify the current physical, security, historical, regulatory or other requirements for performing these tasks on-site and implement appropriate actions to continually remove on-site processing bottlenecks. This may include: revising or eliminating the requirement or task, mitigating the risk associated with the requirement or task, or moving the requirement or task earlier in the processing flow to be accomplished off-site.

LONG-TERM PAYOFF

Establish a USSF Space Mobility Field Command (SMFC) - Akin to the USAF's Air Mobility Command (AMC), SMFC should serve as the space component of the U.S. Transportation Command; a Total Force organization chartered to enable unfettered access to and in space as well as augment AMC's mission to enable global reach through space.

Implement launch operations & sustainment cost share options - Evaluate, socialize and implement cost reimbursement programs to offset recurring government expenditures. The working group identified options that target each group of stakeholders (i.e., infrastructure investors, commercial operators, and space service customers). Fostering private investment in spaceport services has the direct benefit of providing federal, state and local income taxes. [150]

[150] Tax incentives for owning or operating commercial spaceport infrastructure should be offered to encourage investment. A portion of taxes levied should be earmarked for re-investment in spaceport infrastructure and common services (e.g. base security, utility maintenance). Commercial operators should be charged value-added tax on goods and services sold. Consumers should be charged a usage tax, similar to the internet service sales tax levied in six states. (Boesen, U. (2020) States Should Be Allowed to Levy Sales Taxes on Internet Access.Tax Foundation.) It is very important that the timeline for implementing cost share options be commensurate with a period of stable and ubiquitous use of space-based services in order to mitigate the risk of impeding growth in the early phase of this nascent commercial space economy.

Figure 25. In-space servicing, assembly and manufacturing (ISAM) is pivotal to achieving a large-scale, robust and sustainable economy in space. (Credit: SpaceBilt)

IN-SPACE SERVICING, ASSEMBLY AND MANUFACTURING

"Since the dawn of the space age … all of our satellites and spacecraft we send to space have taken their propellant with them and they don't refuel. As the nation invests in new space platforms, we need to develop with that a complementary logistics structure that allows us to refuel, to service and extend lifetime and extend capability."

- GENERAL JOHN E. SHAW[151]

BACKGROUND

Workshop participants were very prolific and provided extensive inputs and recommendations. Transportation and logistics capabilities are critical for any expansive U.S. future across civil, commercial, and military domains. No nation has maintained a dominant position in a domain (air, land, maritime, space, and cyber) without a superior capability for movement and sustainment within that domain. The development of modular, serviceable, and reusable systems and sustainable in-space capabilities is central to expanding humanity's reach and the attainment of a robust space economy.

The In-Space Servicing, Assembly, and Manufacturing (ISAM) toolbox - As a capability area, ISAM represents a wide array of technologies, services, and concepts that enable sustained presence and operation "on-orbit, on the surface of celestial bodies, and in transit between these regimes."[152] Just as vehicles and infrastructure are regularly serviced in other domains (air, land, maritime), the "Servicing" aspect of ISAM refers to the intent to achieve the ability to maintain, repair, or upgrade in-space assets, a departure from the current norms of single-use satellites that are disposed of at end-of-life. Farther down the logistics chain, "Assembly" and "Manufacturing" refer to the assembly of vehicles and infrastructure in space and eventually achieve the ability to manufacture materials in space.

Combined space logistics are foundational - U.S. leadership and superiority in the space domain relies on the development of logistics as it has in other domains, but specific to the space environment. Doing so will require the U.S. to catalyze and leverage the combined commercial, civil, and national security ISAM capabilities, rather than relying on any of those pillars alone.

CURRENT STATE

The U.S. continued to demonstrate leadership in ISAM through numerous demonstrations, achievements, and announcements. Lockheed Martin's In-space Upgrade Satellite System (LINUSS) demonstrated close proximity maneuvering and in-space servicing technologies.[153] OrbitFab announced pricing for delivery of hydrazine to satellites in geosynchronous orbit starting in 2025.[154] Northrop Grumman's Mission Extension Vehicles, MEV-1 and MEV-2, surpassed 5 years of docked service. DIU

[151] Erwin, S. (2022). U.S. Space Command calls for investment in technologies for deep space missions. SpaceNews.
[152] White House (2022). In-space Servicing, Assembly & Manufacturing (ISAM) National Strategy.
[153] Erwin, S. (2023). Lockheed Martin declares success demonstrating tech for in-orbit satellite servicing. SpaceNews.
[154] Foust, J. (2022). Orbit Fab announces in-space hydrazine refueling service. SpaceNews.

released a Commercial Solutions Opening (CSO) to quickly deliver spacecraft beyond geosynchronous orbit.[155] The Space Force's Space Enterprise Consortium awarded the Tetra-5 and Oracle missions, to demonstrate on-orbit refueling and satellite life extension in and beyond geostationary Earth orbit.[156,157] The White House built upon its ISAM National Strategy by releasing the National ISAM Implementation Plan.[158] Additionally, NASA established the Moon to Mars Program Office, cementing the administration's commitment to a long-term presence on the Moon and to support human exploration of Mars and to handle the technical and logistical challenges that come along with it.[159]

Figure 26. Orbit Fab has booked at least four fuel shuttle missions set to launch over the next three years. (Credit: OrbitFab)

Continued growth of ISAM organizations - NASA established the COnsortium for Space Mobility and ISAM Capabilities (COSMIC) to "create a nationwide alliance" and ensure ISAM capabilities are a "routine part of space architectures and mission lifecycles."[160] CONFERS (formerly the Consortium for Execution of Rendezvous and Servicing Operations) expanded its membership to 60 members and continued to support the ISAM industry through development of guiding principles, standards, and policy.[161] The Space Force's Space Systems Command established both a new Commercial Space Office (COMSO) to "oversee the procurement of satellite-based services" and a dedicated program for space mobility and logistics.[162]

Introduction of 5-year deorbit rule by FCC - in a move to address the proliferation of spacecraft and debris in orbit, the FCC instituted a new rule in 2022 to require operators to dispose of their spacecraft "as soon as practicable but no later than five years after mission completion."[163] The increased attention to the problem of orbital debris presents an opportunity for the ISAM community to provide new and increased services to respond to the more stringent requirement.

Maneuver Without Regret becomes Dynamic Space Operations - USSPACECOM pushed for implementation of "Dynamic Space Operations," building on the concept of "maneuver without regret" by recognizing the need for additional capabilities beyond just maneuvering in response to a

[155] Aviation Week (2022). DIU Wants Fast Ride For Small Spacecraft Beyond GEO Space | Aviation Week Network.
[156] NSTLX (2022). Space Enterprise Consortium Awards $50 Million Tetra-5 Contract to Orion Space Solutions - NSTXL
[157] Erwin, S. (2022). Advanced Space wins $72 million Air Force contract for lunar experiment - SpaceNews. SpaceNews.
[158] White House (2022). White House Office of Science and Technology Policy Unveils National In-Space Servicing, Assembly and Manufacturing (ISAM) Implementation Plan | OSTP.
[159] NASA (2023). New Program Office Leads NASA's Path Forward for Moon, Mars
[160] NASA (2023). NASA Creates In-Space Servicing, Assembly, Manufacturing Consortium
[161] Feldscher, J. (2022). CONFERS Highlights: Policy, Transparency, and Future Plans. Payload Space.
[162] Albon, C. (2023). Space Force may hire companies to service orbiting satellites. C4ISRNET.
[163] Jewett, R. (2022). FCC Adopts 5-Year Rule for Deorbiting Satellites. Satellite Today.

contested space environment, including refueling, on-orbit servicing and upgrades, and rapid replenishment and reconstitution.[164]

KEY ISSUES & CHALLENGES

Several participants noted that despite progress over the last year in continuing to develop, demonstrate, and support in-space servicing, assembly, and manufacturing capabilities, headwinds continue to prevent the area from seeing substantial growth. The U.S. must recognize the uncertain venture capital climate and a lack of a mature market present as considerable challenges to ISAM, and develop strategies and a cohesive roadmap to support the fledgling capability area.

Business case, demand signals, and the market remain murky for ISAM - Despite continued development, much of the ISAM capability area does not have a clearly established business case outside of limited examples (spacecraft refueling and life-extension). The demand signals for servicing of non-propellant related commodities (e.g., batteries, solar arrays, payloads), assembly, and manufacturing remain nascent and unsupported by tentpole government contracts and commercial agreements. Government as a whole has yet to establish recurring funding support for ISAM capabilities. Additionally, there are multiple, disparate small organizations claiming to lead ISAM for the government, any of which would require a significant budget increase in order to do so.

> *"Space is no longer the sole domain of governments and aerospace and defense companies. Businesses that pursue emerging opportunities now may gain a first-mover advantage."*
>
> - RYAN BRUKARDT, McKinsey & Co.[165]

Contraction of private investment presents both a threat and an opportunity to ISAM - SSIB participants overwhelmingly noted that they had seen a contract of venture capital over since last year's event. However, whether this contraction will impact the development of ISAM capabilities is uncertain. Forward-looking companies working on the more nascent areas of ISAM may face considerable challenges raising capital, whereas companies with well-supported business models may find funding easier to come by, with the contraction of venture capital acting as a sieve to direct funding to the most successful and laser-focused.

Outdated regulations and laws continue to hamper progress - Export control regulations (ITAR/EAR) inhibit the ability to collaborate with international partners and sell commercial services to foreign customers. International laws and treaties limit the ability for companies to interact with foreign-launched objects, even when they are deemed to be derelict or debris. Overclassification of ISAM capabilities results in duplication of effort between government and commercial, rather than accelerated innovation through collaboration.

Perceived risk is higher than the actual current state - ISAM is still seen as a risk to programs, due to the perceived technical and programmatic concerns. As a result, ISAM requirements (e.g., service

[164] USSPACECOM (2023). Shaw discusses the need for Dynamic Space Operations at the National Security Space Association's 2023 Defense and Industry Space Conference.
[165] Brukardt, R. (2022). How will the space economy change the world? McKinsey & Co.

ports/interfaces for future servicing) are often removed in the preliminary or critical design review phases of missions, in spite of continued demonstration and technology maturation efforts.

Figure 27. Lockheed Martin's In-space Upgrade Satellite System (LINUSS) (Source: Lockheed Martin[166])

KEY INFLECTION POINTS

- **Increased cadence of in-space demonstrations** - both technology maturation and operational, of ISAM capabilities such as refueling, RPOD, servicing, and Active Debris Removal (ADR).
- **Success of forerunner ISAM missions** - such as NASA's OSAM-1 and OSAM-2 and Northrop Grumman's MEV and MRV missions, demonstrating the feasibility of servicing legacy spacecraft and in-space manufacturing and construction capabilities.[167,168]
- **Integration of ISAM requirements into an existing program of record** - or constellation, sending a clear demand signal to industry, establishing the government as an anchor tenant, and supporting the investment of private capital into ISAM businesses.
- **Establishment of clear standards and common interfaces** - would enable industry to focus its efforts on in-space services and operations and encourage interoperability, competition, and open systems architectures.
- **Low-cost launch and affordable access beyond Low Earth Orbit (LEO) -** could serve as a positive or negative influence on ISAM. Increasing access to space beyond LEO supports the need for an in-space logistics chain. Lowering the cost of space launch removes a major barrier to entry for emerging ISAM ventures and relieves the burden of optimized architectures.

[166] Lockheed Martin (2021). Lockheed Martin LINUSS™ Small Satellites Ready for 2021 Launch.
[167] NASA (2022). On-orbit Servicing, Assembly, and Manufacturing 1 (OSAM-1).
[168] NASA (2022). On-Orbit Servicing, Assembly, and Manufacturing 2 (OSAM-2).

However, low-cost launch may also drive a near-term adoption of commoditized spacecraft and reduce the demand for in-space servicing.

- **Without bold action, the United States could be outpaced by foreign competition** - in the implementation of ISAM capabilities into future space architectures. Europe, Japan, and China are all advancing their national capabilities in ISAM, which may lead to standards, interfaces, and commercial services to develop around those established by the U.S.'s peers and competitors, shifting the center of gravity away from the U.S. industrial base.

KEY ACTIONS & RECOMMENDATIONS

SHORT-TERM PAYOFF

Conduct detailed market analyses on ISAM capabilities (e.g., refueling, servicing, manufacturing) for wide dissemination to inform key decision-makers and stakeholders of investment opportunities.

Identify a baseline level of funding for ISAM that will provide greatest return on investment and achieve a "tipping point" status with core sustainment funding from commercial sources.

MID-TERM PAYOFF

Work within the NDAA or other legislation to reduce overclassification and overregulation of RPOD, including identification of the appropriate authorizing organization similar to FAA/FCC/etc. for other areas of space operations.

Assess the outcome of Orbital Prime, a Space Force program aimed at funding a large swath of small businesses to attack the problem of orbital debris. Determine if the program and funding mechanism can be used for future development of ISAM capabilities.

LONG-TERM PAYOFF

Establish a funded challenge for large scale, in-space manufacturing repurposing, assembly, upgrade - to develop ISAM logistics chain beyond refueling and servicing.

Implement ISAM requirements in all new Requests for Proposals (RFPs) - including future-proofing for future capabilities not yet demonstrated, establishing ISAM as a critical capability for all future missions and constellations.

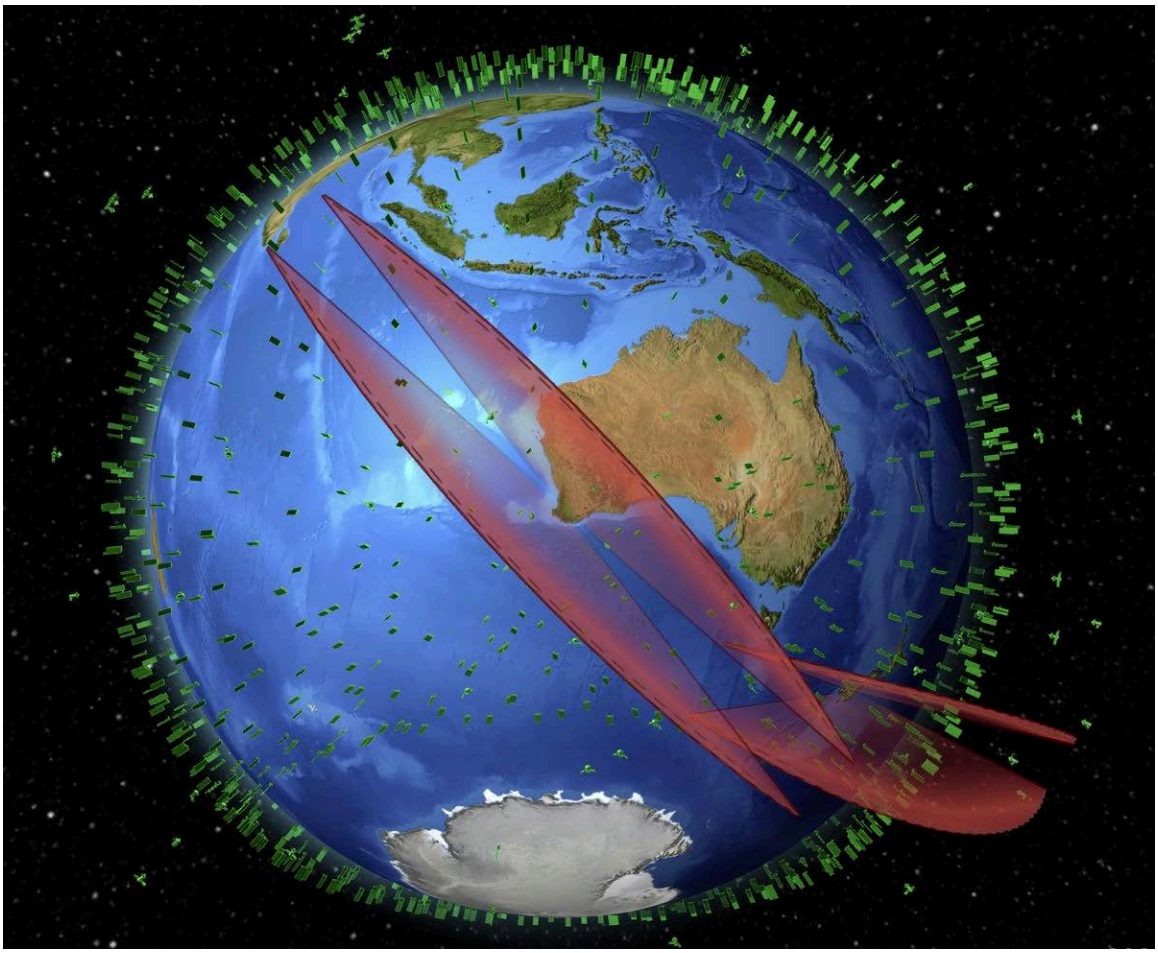

Figure 28. West Australian Space Radar conceptual field of view in LeoLabs Mapping and Analytics Platform (Credit: LeoLabs)

SPACE DOMAIN AWARENESS & TRAFFIC MANAGEMENT

"Awareness precedes action. Without situational awareness, we are blind to the opportunities and dangers that surround us."

-UNKNOWN

BACKGROUND

Last year's report featured Space Domain Awareness (SDA) and Space Traffic Management (STM) as growing mission areas that are distinguishing themselves from remote sensing. This year's SSIB separated remote sensing from SDA/STM so that special focus could be paid to this area. The number of objects in orbit is growing at an exponential rate, particularly in Low-Earth Orbit (LEO).[169,170] The number of space operators is also proliferating across governments and commercial organizations, turning space from a solely military domain where national power could be projected, to one where both national security and economic interests are coexisting. A new global paradigm needs to be adopted to accommodate the diversification and growth of interests in LEO, MEO, GEO, and Cislunar regimes.

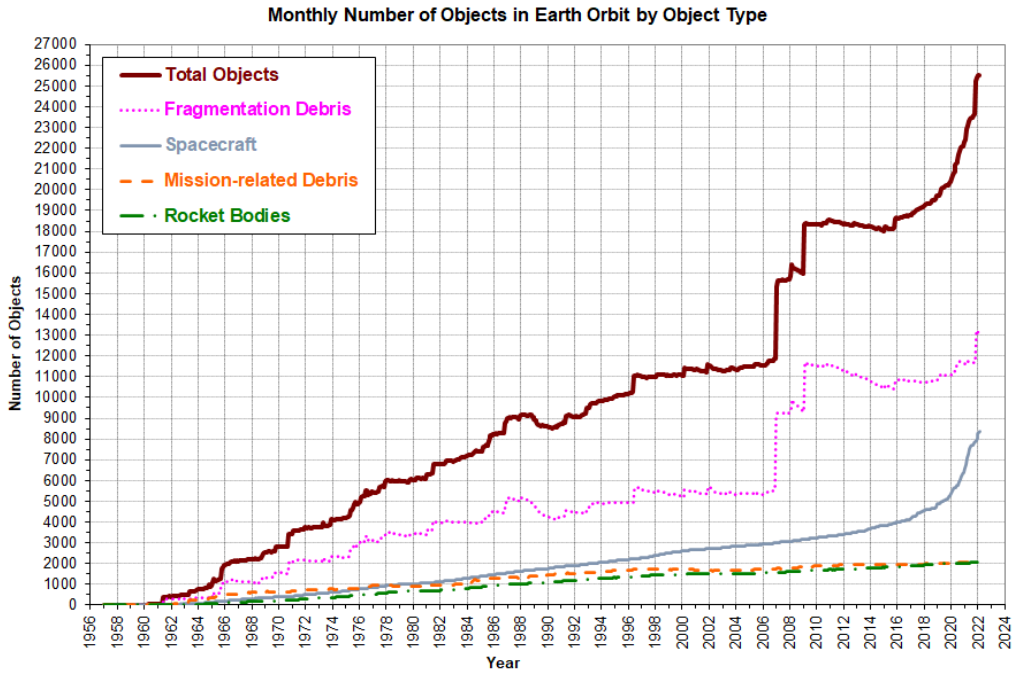

Figure 29: Chart showing number of objects >10 cm in LEO. (Credit: NASA ODPO)[171]

[169] New Space Economy (2022). Space Junk, Space Debris, Orbital Debris – A Quick Overview.
[170] NASA (2023). Orbital Debris Quarterly News 27-1
[171] NASA (2023). LEGEND : 3D/OD Evolutionary Model. NASA Orbital Debris Program Office

This year's SDA/STM Working Group focused on identifying the current state, challenges, inflection points and recommendations for near-, mid- and long-term horizons. The output of this group was robust. Space Domain Awareness is a military-centric mission area focused on the capability to detect, track, identify and characterize space objects and the space environment, in order to promote safety, security, and sustainability. Space Traffic Management is a mission area assigned to the Department of Commerce (DoC) focusing on safety of travel into, through, and from outer space.

CURRENT STATE

U.S. federal agencies are organizing to better support the needs of the growing satellite industry[172,173] - The DoC and DoD signed a Memorandum of Agreement (MOA) formalizing the Departments' relationship for basic space situational awareness (SSA), STM, and coordination for civil and commercial entities. The Federal Communications Commission also stood up a Space bureau in order to better navigate 21st century global communications policy. The working group noted on multiple occasions that without a federal agency to regulate or establish norms for operating, the operating environment may become unsafe to operate.

Lack of sufficient SDA data contributes to on-orbit mishaps[174] or opportunity for adversarial maneuvering - The working group discussed the significant gaps in the orbital operating environment due to sensors not being deployed in sufficient numbers. Such gaps could make operators blind to changes in the orbital environment adding risk to operations.[175] The working group noted the large gaps in awareness also enables greater opportunities for adversaries placing allied operations on a reactionary posture. Companies such as ExoAnalytic this year observed the activity and apparent strategic maneuvering of adversarial satellites, namely China's Shijian-23 (SJ-23) (See Figure 29).

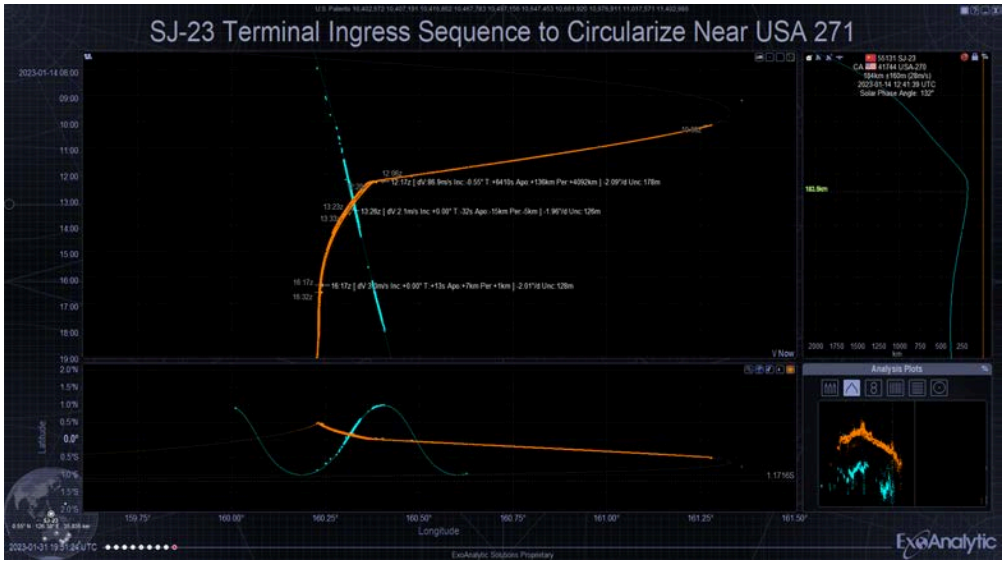

Figure 29: Shijian-23 (orange) approaches a U.S. satellite (cyan) in GEO at high velocity. (Credit: ExoAnalytic)

[172] Office of Space Commerce (2022). Department of Commerce and Department of Defense Sign Memorandum of Agreement to Advance Coordination in Space.
[173] FCC (2023). Launch of FCC Office of International Affairs and Space Bureau.
[174] Cooperative Institute for Research in Environmental Sciences at the University of Colorado Boulder (2022). Minor Geomagnetic Storm, Big Impact: The February 2022 Starlink Satellite Loss.
[175] ExoAnalytic (2023). SJ-21 Quick Look Report (January 2022) & Figure on SJ-23.

Conjunction Events Increase in 2022 - Due in part to the increased number of operational satellites deployed and a net increase of ~2,500 objects in LEO in 2022. A number of companies (led by SpaceX) experienced double digit percentage increases in constellation size in 2022.[176] Additionally, events such as the CZ-6A breakup contributed to the number of fragments on orbit.[177] The working group discussed the large increases in objects in orbit that places many military and commercial activities at risk.

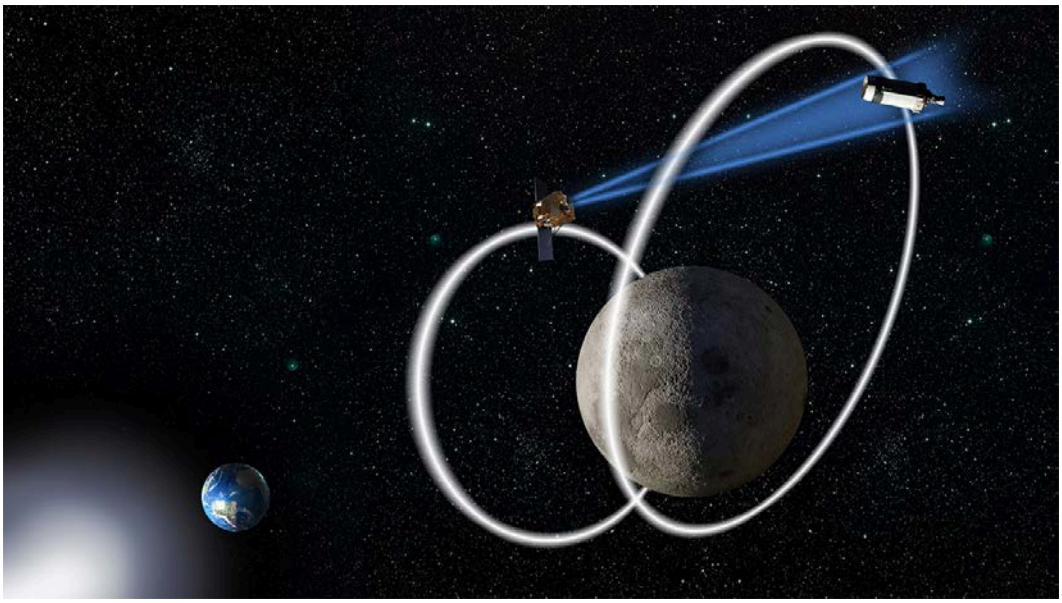

Figure 30: Air Force Research Laboratory's Oracle spacecraft will collect observations of resident space objects in the region near the Moon to maintain space situational awareness in support of the space community and help enable a free and open environment for commerce and space exploration for all. (Credit: AFRL)[178]

Increased activity in Cislunar space requiring greater SDA - The Artemis 1 mission, the first of multiple planned missions to reestablish people on the Moon is one of the more notable examples of increased Cislunar activity in the past year.[179,180] Other missions such as CAPSTONE have launched as well to explore establishing navigation infrastructure in Cislunar regimes.[181] Finally, the working group remarked about how other countries have growing interests in the Moon as well and could be a projection of national power and pride.[182,183]

Space companies are consolidating at a greater pace[184] - Whether it was brought on by the pandemic, or merely an opportunity to become more competitive, space companies are acquiring/being

[176] LeoLabs (2023). What's up in LEO? Insights and analysis from 2022.
[177] Space.com (2022). Chinese rocket body breaks up in orbit after successful satellite launch.
[178] AFRL (2023). Oracle: Space Situational Awareness beyond Geosynchronous Orbit (GEO).
[179] NASA (2023). Artemis.
[180] Space.com (2022). NASA's Artemis 1 mission launched 10 cubesats. Here's how they're doing.
[181] NASA (2022). What is CAPSTONE?.
[182] SpaceNews (2023). First iSpace lunar lander feared lost.
[183] SpaceNews (2023). China unveils lunar lander to put astronauts on the moon.
[184] SpaceNews (2022). Mergers and acquisitions, AEI claims majority stake in York Space Systems, Slingshot acquires Numerica's space-tracking business and UK space data firm Seradata.

acquired, merging, or partnering at an increasing rate.[185] Vendors are integrating once disparate capabilities in order to offer end-to-end systems and services motivated by the promise of larger financial returns. Vertical integration is a double-edged sword. Fewer, yet more-capable companies will be able to offer a greater range of capabilities and services, to include those that directly or indirectly impact the SDA and STM missions. The potential down-side of increasing mergers is the reduction in consumer choice and competition and an increase in prices.

KEY ISSUES & CHALLENGES

The issues and challenges discussed by the working group were connected by the themes of data gaps and latency issues, lack of a clear U.S. policy for investment in commercial space, and regulatory limitations that hinder U.S. commercial development.

Data Gaps & Latency Issues - As mentioned in the "Current State" section, there is a dire lack of sensors to support the SDA mission. However, The U.S. already faces the challenge of ingesting, analyzing, and utilizing the commercial data available from existing sensors and systems, let alone future sources.[186] In addition to data acquisition issues, there is a latency issue between "observe" and "act" in the observe, orient, decide, and act or OODA loop process. What could take operators minutes to hours when coordinating on a potential conjunction event, invariably takes days. As the DoC takes on the responsibility of space traffic management, this will further require the delineation of what types and how much commercial data the various space-oriented government agencies will require - the DoC would seek data on nearly every object in space; whereas, the DoD would seek data relevant to a given mission. Gaps in SA due to actual detection gaps, legacy tools and seams in the space weather prediction framework place U.S. and international systems at risk of safely operating. Another factor in the lack of data for SDA & STM is the lack of communication on space activities between two of the most prolific operators in space, the U.S. and China. Little-to-no transparency into China's space activities makes it difficult to reduce the risks of misunderstandings and miscalculations.[187]

U.S. Policy for Commercial Space Investment - Software development requires less initial capital, potentially yields higher returns on investment, and can demonstrate traction quicker than hardware development.[188] Coupling this with an unclear Government demand signal for commercial space hardware development, pushes markets to focus their capital on software development. A USG Policy of financial and regulatory support in hardware investment would mitigate an unbalanced concentration of capital in software capabilities, and would expand the domestic supply chain.[189] Without a better balance the U.S. advantage remains untapped and leads to the U.S. ceding ground to other nations.

Commercially Limiting Regulations - Restrictions on what data can be collected, such as imagery of other satellites, and unclear rules around data export limit the commercialization of U.S. capabilities. Regulations such as the International Traffic in Arms Regulations (ITAR) or Export Administration Regulations (EAR) were established to prevent the unauthorized transfer of defense-related and

[185] SpaceNews (2022). Major operator consolidation is a long time coming.
[186] DefenseScoop (2023). Space Force must better operationalize commercial data for space situational awareness, GAO says.
[187] SpaceNews (2023). Space Force official: Lack of communication with China increases risk of mishaps in orbit.
[188] TechSpot (2022). Hard vs. Soft: Software may be eating the world, but hardware monetizes better.
[189] BuiltIn (2023). Why Investors Should Prioritize Hardware Over Software Companies.

dual-use technology to potentially threatening foreign entities. However, with the proliferation of commercial space technology and the need for greater collaboration with allies and partners, the risk of these restrictions limiting development and international collaboration may undercut the goal of the regulations which is to protect domestic technologies.

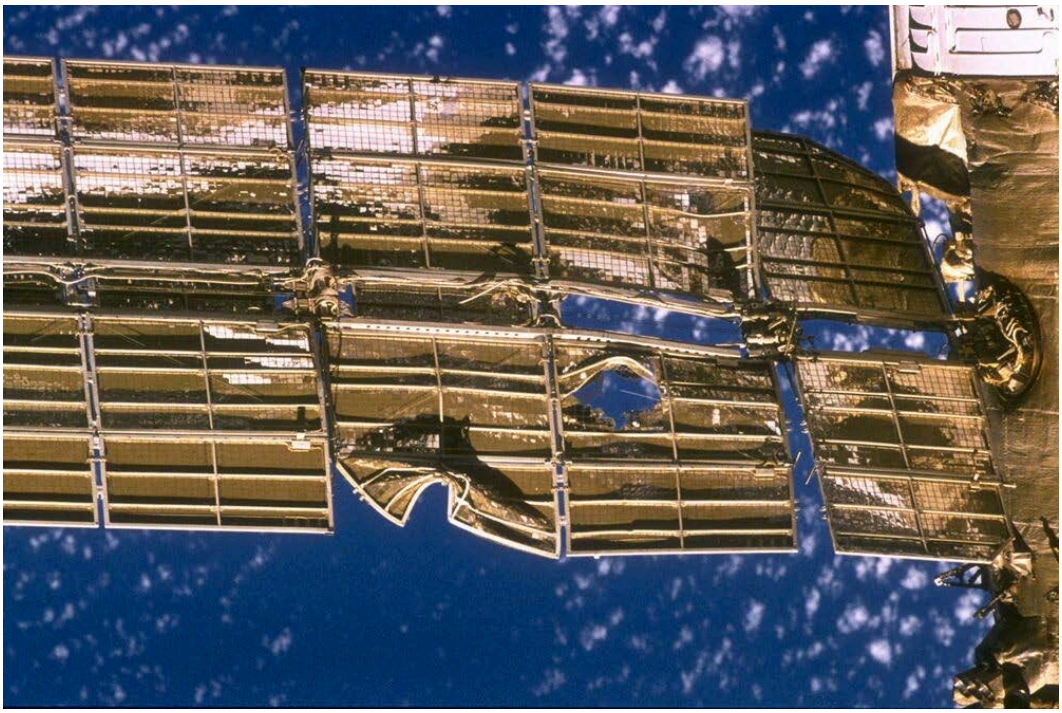

Figure 31: The solar array panel on Russia's Mir Space Station's Spektr Module shows damage incurred by the impact of a Russian unmanned Progress re-supply ship which collided with it in 1997. (Credit: NASA)

KEY INFLECTION POINTS

The workshop participants discussed some possible inflection points that could shift the operating environment for SDA and STM. While these inflection points are hypothetical, they are based on real events.

Expanded launch capability driving down per kilogram price point - The first launch attempt by SpaceX's Starship signaled that the launch industry is on the verge of a massive step function in launch capacity that could bring down the per kilogram price by "orders of magnitude." [190] Such a price drop could enable many businesses to launch satellites in greater numbers and frequency, complicating the operating environment.[191]

Space-to-space events - With higher congestion in orbit the chances of two space objects interacting with each other increases. Two closely related inflection points are the potential collision between two active satellites or space-to-space adversarial action. While collisions have occurred in the past, eliciting fears of a Kesser Syndrome-like scenario, a collision between two active satellites (especially ones that have meaning to the general public) may drive change at a policy level. Also, adversarial action in space causing non-reversible damage reframes the space operating environment from a peaceful one to a place

[190] Twitter (2022). Tweet.
[191] Axios (2023). SpaceX's Starship could transform the space industry.

where there is more national and business risk. National actors have conducted a few, long-term clandestine missions on orbit.[192]

Insurance and regulatory environment overcorrection drives unfavorable business models - Due to the risks and challenges cited previously, an inflection point for the space industry could be that the insurance and regulatory environment overcorrects and begins to offer premiums and policy that smothers U.S. space technology innovation. Companies, in particular, rely on affordable premiums for their space assets and relative freedom to experiment with new business models. Changes in these areas would close off opportunities for both established and nascent ventures.

KEY ACTIONS & RECOMMENDATIONS

These recommendations reflect the numerous inputs from workshop participants and their best assessment regarding which agency(cies) are in the best position to forward the necessary change.

NEAR-TERM PAYOFF

The U.S. adopts a national north star vision to build out SDA/STM capabilities. This communicates a coordinated vision for our partners and allies, and it sends a focused demand signal & revenue roadmap to industry. Focusing on SDA/STM is crucial for ensuring the safety and freedom to operate peacefully in space.

The U.S. creates either a role or agency responsible for coordinating the efforts of the DoD, DoC, DoS, NASA, commercial space, etc. The responsible person/org would ensure operating and technical standards among U.S. departments and agencies, cementing a model for adoption by allies and partners, just as was done with aircraft and maritime traffic safety standards.

The U.S. updates, clarifies, and eliminates no-longer-relevant portions of ITAR and EAR in order to promote greater domestic innovation and competition in space on the global stage.

MID-TERM PAYOFF

Acquisition reform - Only build what you can't buy. Maintaining this philosophy, while speeding our responsiveness as a customer, keeps the U.S. DoD capabilities in space at the leading edge.[193]

Establish and enforce rules for space traffic management and right-of-way.[194] Doing so assigns responsibility for collision avoidance and establishes norms for the international space community to follow.[195]

Expand the data collection, fusion, and analysis architecture (mil, comm, civ, etc.) in order to drive open, transparent, and credible international standards, policies, and practices to promote responsible global space traffic coordination.

[192] Business Insider (2023). China lands its secretive space plane after 9 months in orbit.
[193] Space Systems Command (2022). Space Systems Command Celebrates First Anniversary as USSF Field Command.
[194] Science Direct (2022). Looking for the Rules-of-the-Road of Outer Space: A search for basic traffic rules in treaties, guidelines and standards.
[195] Federal Aviation Administration (2021). Compliance, Enforcement & Mishap.

LONG-TERM PAYOFF

Continuously replenish and refresh the SDA/STM infrastructure for public/private partnerships in order to maintain and improve persistent coverage from LEO to Cislunar and beyond.

Enforce an international standard for all satellite owner-operators to publish position data, agree upon safety & conjunction rules, and utilize real-time communications with integrated sensors and data from space and ground assets in order to reduce radio frequency litter and improve safety of navigation.

Figure 32. When fully operational, the Pelican constellation replenishes and upgrades Planet's existing high resolution SkySat fleet with better resolution, more frequent image revisit times, and reduced reaction time and latency. (Credit: Planet)

REMOTE SENSING & GEOSPATIAL ANALYTICS

"A lack of transparency results in distrust and a deep sense of insecurity"

- DALAI LAMA

BACKGROUND

Remote sensing has long been a prominent subject in SSIB reports, but SSIB'23 introduced Geospatial Analytics as a novel and complementary topic. This year's agenda aimed to address pressing issues faced by commercial remote sensing providers. The working group covered a broad spectrum of topics, including the regulatory framework and mission authorization processes. It also delved into the challenges associated with government product acquisition for commercial remote sensing providers, considering the complexities that arise from operating in diverse classification environments and barriers to entry in the industry. Furthermore, the discussions encompassed emerging trends in the militarization of civilian remote sensing assets and geospatial analytics, highlighting their significance in the field of commercial remote sensing.

Global Remote Sensing Continues to See Rapid Growth - 2022 and early 2023 have been another high visibility year, as commercial remote sensing providers are shedding light on global trends, disasters and conflicts, such as the breach of the Kahkova Dam in Ukraine.[196] Growth trends in the industry remain strong, even with economic uncertainty. Industry analysts expect the remote sensing services market to double to $27B by 2027 (14.9% CAGR).[197] The growth in launch availability and cost reductions have continued to enable commercial providers to rapidly and affordably grow their constellations.[198] The U.S. Intelligence Community awarded its first commercial remote sensing service contracts through the NRO Commercial Systems Program Office (CSPO) for the Electro-Optical Commercial Layer (EOCL).

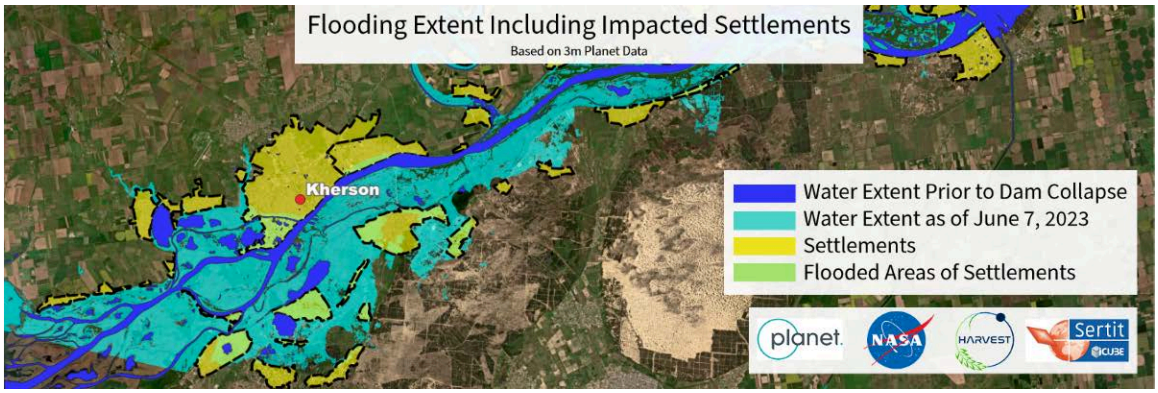

Figure 33. Flooding extent in the vicinity of Kahkova Dam in Ukraine (Credit: NASA)

[196] NASA Harvest (2023). Navigating the Kakhovka Dam Collapse: NASA Harvest Consortium Assesses Agriculture Impacts with Satellite Imagery

[197] Markets & Markets (2023).Remote Sensing Services Market--Global Forecast to 2027.

[198] Roberts, T. (2022). Space Launch to Low Earth Orbit: How Much Does It Cost?. Aerospace.

Geospatial Analytics Sees Rapid Growth Parallel to the Remote Sensing Industry - but with associated challenges - Geospatial Analytics services industry is growing alongside the increase in remote sensing sources, however the amount of data being served is not being served in products that are usable by customers. Currently customers on the commercial side as well as government side can buy pixels, buy time on a remote sensing asset, buy subscriptions to data access, can "rent/stream" pixels - however users on all ends of the spectrum are limited by the need of using specialized tools and user interfaces to make sense of the data. The inclusion of AI/ML techniques, multi-sensor data fusion, the need to process massive amounts of data (on the petabyte scale), cloud/edge processing, site specific change detection are all commercial trends in this area.

CURRENT STATE

Ongoing world events highlighted the continuing need for commercial remote sensing operators and their products. While demand has increased from the Department and Defense and Intelligence Community, larger economic factors have decreased the availability of private funding available to commercial providers. With the tightening of funding lines and increased competition, providers are looking to diversify their user base outside of the DoD and experienced Geospatial Information Systems users.

USG Continues to Embrace Commercial Remote Sensing - In 2022, there was significant growth and opportunity in the commercial remote sensing industry, primarily driven by the successful utilization of commercial imagery during the ongoing Ukraine Conflict. The NRO CSPO expanded its programs in commercial remote sensing, establishing a program of record for Electro-Optical Commercial Layer (EOCL) providers, and is on the path to do the same for other remote sensing modalities, validating the need and place for commercial providers. Furthermore, the NRO onboarded new partners, including Airbus U.S., Capella, Iceye U.S., PredaSAR, and Umbra, to evaluate additional commercial capabilities. In a notable development, the NRO extended its portfolio to include its first commercial Radio Frequency (RF) sensing partner, Hawkeye360, and also extended existing contracts while awarding new ones for commercial hyperspectral imaging.

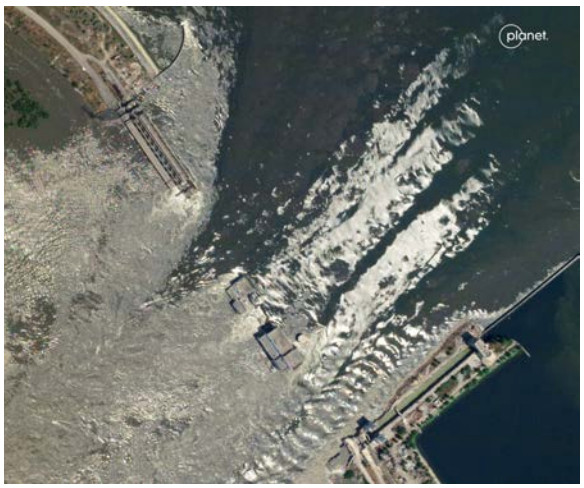

Figure 34. Destruction of the Kakhovka Dam, Ukraine, on 6 June 2023 (Credit: Planet) [199]

Increased Competition and Decreased Private Funding Availability - Macroeconomic headwinds have decreased the availability of venture capital funding by 53% YoY (Q1 2023),[200] leading to increased

[199] Picture Caption: Planet (2023). Destruction of the Kakhovka Dam.
[200] Teare, G. (2023). Global VC Funding Falls Dramatically Across All Stages In Rocky Q1, Despite Massive OpenAI And Stripe Deals. Crunchbase.

competition for available private funding. Additionally, launches of foreign commercial remote sensing, such as China's commercial space sector (which includes many Chinese-state owned companies) has increased competition in the international market for U.S. providers.[201]

KEY ISSUES & CHALLENGES

A number of issues and challenges were identified by the working group participants that affect the growth and stability of commercial remote sensing and geospatial analytics. These ranged from uncertainty in the market size and growth to competition within industry, with government, and internationally – both allies and adversaries. As with feedback received from 2022's State of the Space Industrial Base working group, this year's group continued to perceive policy, regulation, and processes (i.e., bureaucracy) as an ongoing issue--without much progress made over the last year to alleviate.

Stability and growth of market demand - While the conflict in Ukraine has driven both awareness and demand for remote sensing data and analytics, working group participants noted the need for broader awareness of commercial capabilities outside of traditional geospatial teams and customer base. Government demand signals for commercial remote sensing data are increasing, but with financial turbulence anticipated in the near future and a high likelihood of an increasingly difficult venture capital climate, companies will need to continue to improve the profitability and marketability of their products to new sectors.

Government competition with industry - Despite growing use of commercial remote sensing and increasingly significant funded commitments such as the NRO's EOCL contracts,[202] the U.S. government continues to field remote sensing assets that actively compete or are seen as blocking out commercial companies. The DoD and IC maintain robust acquisition programs of ISR assets, NASA maintains the Landsat satellite program with the launch of Landsat NeXt in 2030,[203] and NOAA maintains the GOES and JPSS programs with follow-on launches planned throughout the 2020s and 2030s.[204] While commercial remote sensing often cannot match the full capabilities of national assets, a recent GAO report noted that "according to senior NGA officials, commercial satellite companies meet nearly 98% of NGA's mapping mission requirements"[205] serving as an indicator that industry may be closer to being able to provide more capability than the allocation of funding to national assets versus commercial data would suggest.

Bureaucracy Continues to Hamper Progress - An ongoing challenge for the industry remains the tangled web of classification, the Authority to Operate process, cybersecurity and Controlled Unclassified Information (CUI) requirements, spectrum allocation, and licensing which slow and hinder innovation and new entrants. As explained in a recent piece on Space Mission Authorization:

[201] Erwin, S. (2023). U.S. intelligence report: China's commercial space sector to become global competitor by 2030 - SpaceNews. SpaceNews.
[202] NRO (2022). NRO announces largest award of commercial imagery contracts.
[203] NASA (n.d). Landsat Next: A New and Revolutionary Landsat Mission.
[204] NESDIS (2023). Currently Flying.
[205] GAO (2022). National Security Space: Actions Needed to Better Use Commercial Satellite Imagery and Analytics.

"The U.S. regulatory regime authorizing and overseeing commercial space missions is responsible for one of the most dynamic and technologically advanced industries in the world. Recently, however, investment in the space industry has slowed. This is happening in part because the rate of innovation and diversity of recent technologies enabling novel space missions is beginning to outpace the regulatory regime's ability to provide industry with optimal predictability. The current requirements require firms to navigate a complex web of federal agencies, with companies' expectations regarding approval resting largely on prior experience; approval for innovative concepts is particularly difficult, as no such experience exists. This element of the unknown leads to hesitancy for potential investors in new and exciting technologies, reducing industry's ability to translate innovative ideas into fielded capabilities. The regulatory regime is simply not keeping pace with the rate of commercial space innovation." [206]

KEY INFLECTION POINTS

- **Competition versus consolidation will determine the robustness of the remote sensing industry** - Increased competition from new entrants will result in greater capabilities and growth, whereas the possibility of commercial remote sensing companies to be acquired or otherwise consolidated under traditional contractors is seen as an action that will stifle innovation.
- **Funding, both government and private, could make or break the industry** - The possibility of near-term financial turbulence could cause a contraction in venture capital investment. Meanwhile, government funding in commercial remote sensing is growing, the lack of ample "significant contracts" and commitments persists.
- **Reduced launch costs and increased launch cadence will lower the barrier to entry for companies building new capabilities and space systems** - As with the other industry working groups participating in the 2023 State of the Space Industrial Base, the ability to quickly and inexpensively field new space assets is seen as a crosscutting capability that will fuel growth in commercial remote sensing, among other space technology areas.
- **Direct threats to on-orbit assets are a growing concern**, especially as commercial remote sensing data is increasingly being used to augment national capabilities and provide insights into ongoing conflicts (e.g. Ukraine).

KEY ACTIONS & RECOMMENDATIONS

SHORT-TERM PAYOFF

Designate the Space Sector as critical infrastructure - There are 16 critical infrastructure sectors whose assets, systems and networks, whether physical or virtual, are considered so vital to the United States that their incapacitation or destruction would have a debilitating effect on security, national economic security, national public health or safety, or any combination thereof. Designating the Space Sector as Critical Infrastructure would rightfully place Space technology in a place where the federal

[206] Clayzon, Z., Spellman, F., Patel, S. & Shen, D. (2023). Space Mission Authorization: Enabling the Final Frontier. War on the Rocks.

government would need to have a formalized leadership role and coordinate national efforts to protect this sector.

MID-TERM PAYOFF

Develop fair and equitable End User License Agreements (EULAs) - Current EULAs between the commercial remote sensing providers and the U.S. Government often undermine commercial business pricing, and more open standards on data sharing rights.

Expand USG budgets for commercial remote sensing and geospatial analytics data purchases - Gradually expanding budgets for commercial remote sensing efforts and keeping these budgets consistent year-over-year will help foster the growth of the U.S and allied remote sensing sector.

LONG-TERM PAYOFF

Consolidate the regulatory regime for Space Mission Authorization - The Department of Commerce should be the sole point of contact and final licensing authority for companies conducting space missions - with companies being able to apply to an Office of Space Commerce. The processes relevant to continuing supervision, safety, launch and reentry, and spectrum will continue in their current form but under an interagency process led by the Department of Commerce. For example, the Federal Aviation Administration would continue to sign off on launch and reentry, but it would do so as part of the Department of Commerce's interagency process for each application. The Federal Communications Commission and the National Oceanic and Atmospheric Administration would likewise retain their authorities in a similar arrangement. Input and cooperation from these agencies are crucial for responsible growth of the commercial space industry, but the Office of Space Commerce should manage the process from application to final licensing (See footnote 11).

Reforming the Small Business Innovation Research (SBIR) and Small Business Technology Transfer Research (STTR) grants - The DoD SBIR program awards a disproportionate share of Phase I/II funding to a set of companies that, based on extensive past performance data, are unlikely to deliver capabilities to defense end-users. The top 25 companies with the most Phase I/II awards (0.53 percent of 4,703 cited in the Bresler study) received 18 percent of all Phase I/II funding (average of $92M in Phase I/II awards per company). 24 of these 25 companies have been receiving SBIR awards from the DoD for more than 10 years, 20 of them for more than 20 years. This must be directly reformed as over-investment in a small number of companies that do not transition scalable capability to warfighters is a national security problem of its own.[207]

[207] DoD (2023). Terraforming The Valley Of Death.

Figure 35. Vice President Kamala Harris speaking at a meeting of the National Space Council Users' Advisory Group (UAG) in February 2023. The UAG is an advisory body that ensures the interests of industry, other non-Federal entities, and other institutions involved in leading aerospace research, science advancement, technology development, and space operations are represented in a balanced fashion within the National Space Council. (Credit: The White House)

POLICY & FINANCE

"2024 will be a critical year, and we must resolve to unleash the full potential of every part of the U.S. space economy and reassert our place leading the free world in discovering, exploring, and using space for the betterment of humanity."[208]

-- CHARLES BEAMES, Chairman, Small Satellite Alliance

BACKGROUND

This sector received dynamic inputs from a host of participants, who were strongly motivated by the current geo-political and geo-strategic environment. Russia's illegal full-scale invasion of Ukraine continues to be foremost on the mind for members of the national security space community stakeholders. The conflict underscores the growing role the commercial space sector plays during times of crisis and conflict. In turn, the crisis is stoking a renewed sense of urgency on behalf of the U.S. Government to create a broader space policy and provide a financial means that ensures both a robust and thriving space industrial base while ensuring continued freedom of access to space. The 2022 State of the Space Industrial Base (SSIB) report highlighted various actions that the Biden Administration and Congress took related to the space sector, including measures to strengthen and expand the industrial base, coordinate with allies and partners, improve U.S. infrastructure, and reinforce U.S. technological competitiveness.

The potential of the space sector and its recent developments are unfolding against the backdrop of increasing competition with the People's Republic of China. According to the Australian Strategic Policy Institute, the United States remains a market leader in the space sector, especially with regards to small satellites and space launch systems.[209] To keep up with the growth of the global space market, stakeholders expressed that the U.S. Government needs to encourage further private sector investment, coordinate space policy across government entities, and bridge a widening gap between industry and government. This requires deeper collaboration between technology specialists, venture capitalists, startups, banks, state and local institutions, academia, the U.S. Government, our allies and partners to ensure lasting investments and policy coordination across the space sector.

Over the last year, the U.S. Government signaled its prioritization of the space sector with the release of key space policy documents and the establishment of new space and financial offices to include:

- USSPACECOM Commercial Integration Strategy Overview[210]
- Department of Homeland Security (DHS) Space Policy[211]
- DoD Directive 3100.10 Space Policy[212]

[208] Beames, C. (2023). The Space Force's 2024 Resolution: Forget The 90s—Buy Into The 2020s. Forbes.
[209] Australian Strategic Policy Institute (2023). ASPI's Critical Technology Tracker - Sensors and Biotech update, Appendix 1.1: Top 5 Country Visual Snapshot, Page 55.
[210] USSPACECOM (2023). Commercial Integration Strategy Overview. Defense.gov.
[211] Mayorkas, A. (2022). DHS Policy Statement 063-01, Revision 01: DHS Space Policy. DHS.
[212] DoD (2022). DoD Directive 3100.10, "Space Policy," August 30, 2022.

- Department of Commerce (DoC) and DoD Sign Memorandum of Agreement to Advance Coordination in Space[213]
- White House National Cislunar Science & Technology Strategy[214]
- DoD Establishes the Office of Strategic Capital (OSC)[215]
- White House National Preparedness Strategy & Action Plan for Near-Earth Object Hazards and Planetary Defense[216]
- White House National In-Space Servicing, Assembly, and Manufacturing Implementation Plan[217]
- Federal Communications Commission (FCC) Establishes the Space Bureau[218]
- DoD National Defense Science & Technology Strategy[219]
- Department of State Strategic Framework for Space Diplomacy[220]

While an important step forward, stakeholders noted a continued disconnect remains, owing to a misalignment between incentive structures utilized by the U.S. Government and the business needs of commercial entities working in the space sector. Some stakeholders felt that the U.S. Government and its *officials tend to overestimate the impact space policy documents and high-level statements have in terms of driving agency funding*. Additionally, stakeholders felt that in order to make policy documents more useful, the *U.S. Government needs to link policy to agency funding decisions*, including the alignment of incentives and an increased flexibility in funding mechanisms offered.

Over the last five years, the U.S. Government has established a number of new entities focused specifically on providing guidance and regulations and developing capabilities in the space domain to include: USSF (December 2019), National Security Innovation Capital (NSIC; March 2021),[221] SpaceWERX (August 2021), the USSF Commercial Services Office (2022), Office of Strategic Capital (December 2022), USSPACECOM Commercial Integration Office (April 2023), and FCC Space Bureau (April 2023).[222] While the creation of these entities signals the growing importance of the space sector, the strategic direction and financial actions taken across agencies are not coherent or coordinated. To continue to build our enduring advantage, the commercial sector requires clear

[213] DoC (2022). Department of Commerce and Department of Defense Sign Memorandum of Agreement to Advance Coordination in Space.
[214] White House (2022). National Cislunar Science & Technology Strategy.
[215] DoD (2022). Secretary of Defense Establishes Office of Strategic Capital.
[216] White House (2023). National Preparedness Strategy and Action Plan for Near-Earth Object Hazards and Planetary Defense.
[217] White House (2022). National In-Space Servicing, Assembly, and Manufacturing Implementation Plan.
[218] Wiquist, W. (2023). FCC Space Bureau & Office Of International Affairs To Launch Next Week. FCC News.
[219] DoD (2023). National Defense Science & Technology Strategy 2023.
[220] Blinken, A. (2023). United States Leads in Space with Diplomacy. State Dept.
[221] NSIC (n.d.). National Security Innovation Capital.
[222] Wiquist, W. (2023). FCC Space Bureau & Office of International Affairs to Launch Next Week. FCC News.; Erwin, S. (2022). New Space Force procurement shop subscribes to the space-as-a-service model - SpaceNews. SpaceNews.; Hitchens, T. (2023). SPACECOM plans new, unified 'Commercial Integration Office' to work with private firms. Breaking Defense.; AFRL (2021). SpaceWERX launch drives AFWERX small business focus on universities and on-orbit capability. AFRL.

guidance from both these new and existing stakeholders across the U.S. Government's broader space regulatory and policy regime. [223]

CURRENT STATE

In the last year, the space sector globally has made significant strides, by growing to $447 billion in 2022 with the potential to grow to $1 trillion by 2030.[224] The costs of satellites and heavy launches continue to fall in U.S. dollars per kilogram, and the number of space startups more than doubled to 600 in 2022, up from around 250 in 2010.[225]

However, rising interest rates, inflation, and recent macroeconomic volatility are increasing the costs and lowering the availability of capital. A report from Space Capital found that investment in space startups fell 58%, from $47.4 billion in 2021 to $20.1 billion in 2022.[226] Additionally, various publicly traded space companies have experienced significant (greater than 50+%) declines in share price since 2022. In March 2023, the failure of Silicon Valley Bank and Signature Bank shook the startup sector due to the large amount of capital deposits they held from both venture capital investors and companies deposited there. The ramifications of these bank failures could be felt in Israel and Switzerland.[227] With space companies traditionally viewed as riskier investment opportunities by private investors, these tightening financial conditions are likely to have a disproportionately negative impact on space investment relative to other technology-related sectors. Venture financing across all investment stages fell 53% in the first quarter of 2023, compared to the 2022.[228]

Lastly, the stakeholders were very vocal about their frustrations with how the U.S. Government is not utilizing the full range of financial mechanisms and instruments at its disposal to advance the commercial space sector. The establishment of OSC was welcomed, and its planned use of leveraging debt to fund projects was viewed as a positive development on top of grants that the U.S. Government often provides to small business entities. However, stakeholders discussed at length the other financial mechanisms that have not been leveraged by the U.S. Government, to include equities, commodities, derivatives, and insurance, as well as under-used institutions under-utilized like the Export and Import Bank, the National Security Innovation Capital (NSIC), or potentially creating a space-focused In-Q-Tel-like entity created to encourage more space investments.[229]

The U.S. Government is a powerful financial trendsetter, and government contracts are a key signal private investors use when making investment decisions. Thus, the U.S. Government can play a unique role in spurring further space investment by launching new space-related financial tools and effectively communicating its priorities to venture capitalists, late-stage technology investors, investment banks, and other financial entities. The establishment of NSIC to invest in dual-use hardware companies and OSC to use loans and loan guarantees into national security areas like the commercial space sector signal

[223] Office of Space Commerce (2023). Legal and Departmental Authorities of the Office of Space Commerce.
[224] McKinsey (2023). A giant leap for the space industry.
[225] Ibid.
[226] Werner, D. (2023). Space Capital sees upside to 2022 decline in space investment, SpaceNews.
[227] Scheer, S. (2023). Analysis: Israel's tech sector reels from SVB collapse, proposed judicial reform. Reuters.
[228] Kilpatrick, C. (2023). The Party's Still Over: The VC Downturn In 6 Charts. Crunchbase News.
[229] In-Q-Tel (n.d.). About IQT - In-Q-Tel.

that the U.S. Government is implementing novel approaches to deploy non-traditional financial mechanisms.[230]

KEY ISSUES & CHALLENGES

Commercial Market is Nascent, U.S. Government remains an Anchor Customer - The commercial market for space products and services is rapidly growing, but the U.S. Government remains the largest customer. As the anchor customer, the U.S. Government's requirements are the primary market signal that guide the commercial sector entities research and development decisions of commercial sector entities.

High-Level Statements Not Matched with Financial Allocation - Recent high-level statements and policy documents advocate for more rapid and higher levels of acquisition and procurement of space products and services, but these calls have not translated into changes in acquisition or funding allocation at the program level. Current promotion, incentive, and compensation structures are incompatible with senior-level leadership messaging.

Space Policy and Regulatory Regime is Siloed and Outpaced by Technology Advancements - Commercial space vendors must receive licenses and approvals from multiple U.S. Government agencies before putting a product in space. With the creation of new entities such as the FCC Space Bureau to regulate policy and licensing concerning satellite and space-based communications and activities, there are more stakeholders that the commercial sector needs to engage, increasing the costs and slowing the pace of innovation.[231] Furthermore, each organization publishes policy and doctrine which lack a common set of definitions or terms, creating confusion between government agencies and between the government and the commercial sector.

Space Government Acquisition is Slow and makes Small Bets - The existing government acquisition & procurement process takes five to ten years and is largely dominated by defense primes.[232] In particular, the defense budget is established two years in advance of allocation, creating a time-delay between commercial advancements and budget decisions.[233] In addition, the U.S. Government's approach of seeding hundreds of space startups is unstainable. Stakeholders underscored the need for the U.S. Government to allocate larger capital amounts to fewer companies to enable companies to rapidly scale and reach a sustainable economy of scale.

[230] DoD (2022). Secretary of Defense Establishes Office of Strategic Capital.
[231] FCC (2023). FCC Space Bureau & Office of International Affairs Launches April 11
[232] Patt, D. and Greenwalt, W. (2021). Competing in Time: Ensuring Capability Advantage and Mission Success through Adaptable Resource Allocation. Hudson Institute.
[233] Ibid.

Space Sector Requires Higher Levels of Patient Capital - Several commercial space companies highlighted the capital-intensive needs and longer time frames required for space development. According to AngelList, the average amount of seed funding tends to be under $2M, and Series A funding is between $2M and $15.[234] However, stakeholders noted that putting a product into space costs a minimum of $5M, meaning that thus providing less than $5M in seed money to a space commercial sector start-up sets that company up for failure. U.S. Government institutions such as the National Security Innovation Capital, SPACEWERX, Defense Production Act Title III, U.S. Export-Import Bank, and the newly established OSC have largely relied on grants to spur the space industrial base. As the market matures, it is critical for investors and the U.S. Government to expand their financial mechanisms utilized to include debt, equities, commodities exchange, insurance markets, and derivatives. A commodities exchange would standardize space products and services and enable investors to better visualize and predict market opportunities and risk.[235] Additionally, the ever-growing amount of space debris combined with the increasing number of new satellites is creating higher risks of collision. [236] As the number of space launches rises, so too does the risk that comes from space debris, which already threaten satellites already orbiting around the Earth.[237] Insurance markets and institutions have been hesitant to insure satellites being launched into Low Earth Orbit (LEO), and when insurance is offered, collision damage is excluded completely.[238] These additional financial mechanisms will provide the necessary risk assurance and larger amounts of patient funding to further scale the space sector. As the anchor customer, the U.S. Government can play a critical leadership role in developing and participating in these new markets and financial instruments.

Export Controls Restrict Technology Transfer and International Collaboration - The International Traffic in Arms Regulations (ITAR) regime established the regulations for the export and import of defense-related items that fall under the United States Munitions List (USML).[239]

Stakeholders expressed frustration that U.S. companies were unable to export space products that are already available across international markets by companies from allied or partner nations. Additionally, the various ITAR restrictions that companies have to comply with can hinder technology transfer, thus limiting U.S. companies' access to global supply chains and talent.[240]

Different Space Nomenclature in Government and Commercial Sectors - A gap continues to persist between the U.S. Government and the space commercial sector when it comes to lexicon and nomenclature. The same language, like "commercial" or "valley of death," can mean different things to a DoD acquisitions specialist, venture capitalist, or private sector entity.[241] Additionally, there is a lack

[234] Angellist (n.d.). Round.
[235] Cahan, B., Pittman, B., Cooper, S. and Cumbers, J. (2018). Space Commodities Futures Trading Exchange: Adapting Terrestrial Market Mechanisms to Grow a Sustainable Space Economy. NewSpace Journal.
[236] NASA (2023). NASA Orbital Debris Program Office.
[237] Daehnick, C., Gang, J. Rozenkopf, I. (2023). Space launch: Are we heading for oversupply or a shortfall?. McKinsey & Co.
[238] Hussain, N. and Cohn, C. (2021). Launching into space? Not so fast. Insurers balk at new coverage, Reuters.
[239] National Archives (2023). Code of Federal Regulations Title 22, Chapter I, Subchapter M, Part 120 -- Purpose and Definitions. eCFR.; National Archives (2023). Code of Federal Regulations Title 22, Chapter I, Subchapter M Part 121 -- the United States Munitions List. eCFR.
[240] Abbey, G. and Lane, N.(2009). The First Barrier: The Impact of Export Controls on Space Commerce. American Academy of Arts & Sciences.
[241] Landreth, J. (2022). DAU News - Through DoD's Valley of Death. DAU (via Archive.org).

of familiarity with the private sector and commercial markets amongst the U.S. Government personnel responsible for the space industrial base. This can translate into policies that do not reflect the signals that the commercial sector is looking for.

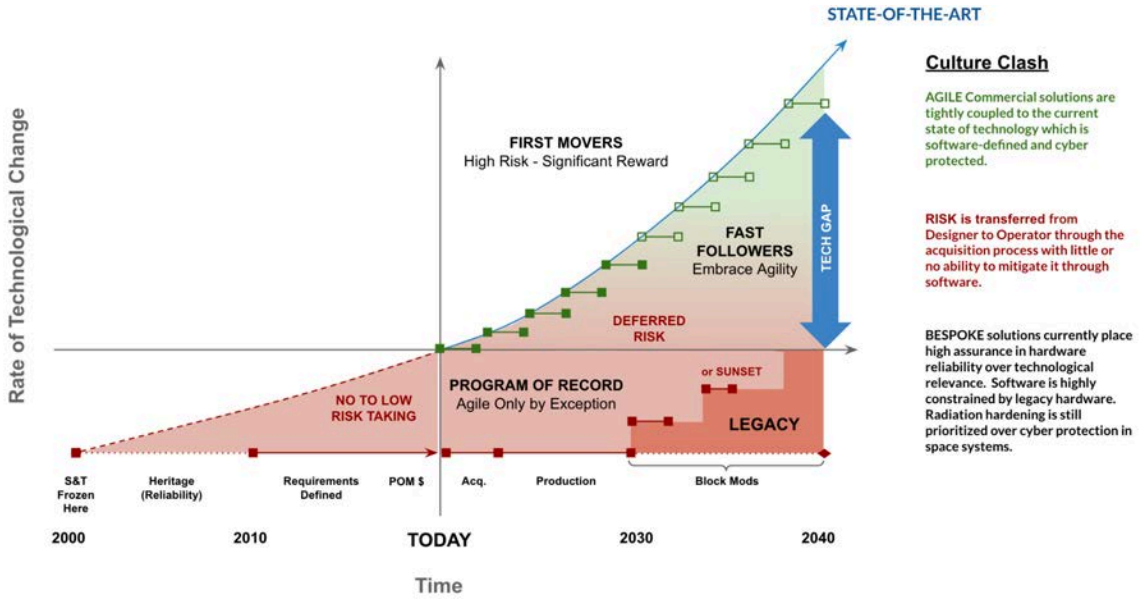

Figure 36. The widening technological gap between software-defined, agile commercial tech and deliberately planned, requirements-based government procurement programs. The commercial sector readily adopts today's technology and fast follows the state-of-the-art with a focus on the future, while the government sector favors long-proven technology and favors designs to meet well-defined requirements that were validated based on conditions in the past. (Credit: DIU)

KEY INFLECTION POINTS

- Commercial market demand surpasses U.S. Government demand, signaling that the commercial sector has the ability to drive space developments rather than relying on the U.S. Government.
- Public sector remains the anchor customer, indicating that space products and services will remain a niche market without wider commercial applications or use.
- U.S. Government regulations and policy remain one- to-two product life cycles behind the commercial sector, slowing commercial innovation and market creation and incentivizing firms to consider moving to a more regulatory-friendly country to remain globally competitive.
- U.S. companies can readily collaborate and sell space products and services abroad, enabling the U.S. space industry to compete internationally and incur more revenue over time and ensure access to global talent and supply chains.

KEY ACTIONS & RECOMMENDATIONS

SHORT-TERM PAYOFF

Designate the Space Sector as a Critical Infrastructure Sector - According to DHS's Cybersecurity and Infrastructure Security Agency (CISA), the U.S. Government has officially

designated 16 critical infrastructure sectors, both physical and virtual, that if compromised would significantly harm the United States.[242] Of these 16 critical infrastructure sectors, four – communications, defense industrial base, information technology, and transportation – directly touch the space industrial base. By formally adding space to the list of 16 critical infrastructure sectors, the space sector will gain the same "full faith and credit" that other sectors possess to support further development. The space sector can be designated a critical infrastructure sector through a Presidential Policy Directive or Homeland Security Presidential Directive.[243]

Allocate Larger Amounts of Capital to Fewer Companies - The U.S. Government should allocate larger amounts of capital to fewer space companies to establish a strong demand signal and rapidly scale -up production of space products and assets. These contracts need to be awarded in alignment with government timeline commitments.

Examine and Expand the Professional Opportunities for Public and Private Sectors' Workforce Cross-Pollination - The U.S. private and public sectors suffer from stovepiping and a lack of understanding by personnel within each sector of the other. Within the context of the space industrial base, the U.S. Government is unaware of the capabilities that industry has, and the industry does not understand the U.S. Government demand signals that can drive research and development decisions. U.S. Government personnel (civilian and military) that work in the acquisition field and program offices should be provided more opportunities to serve a year in the private sector at large financial institutions like banks, hedge funds, and venture capital firms as well as technology companies and start-ups. Conversely, the U.S. Government should allow for private sector and industry personnel to serve in a year across the acquisition and program office billets. Therefore, the U.S. Government should examine current opportunities that allow civilian and military acquisition and program office personnel to spend time in the private sector and vice versa. These opportunities, wherever possible, should be drastically expanded.

[242] CISA (n.d.). Critical Infrastructure Sectors | CISA.; CISA (2022). Cybersecurity Directives | CISA.
[243] Ibid.

MID-TERM PAYOFF

Streamline and Align Export Regulatory Regime to International Market Conditions - The existing ITAR regime is not keeping pace with the rapid availability of space products and services on the global market. To increase U.S. exports, strengthen supply chain resiliency, and expand international collaborations and technology transfers, the export regulatory regime needs to be aligned, streamlined, and able to keep pace with the conditions of international markets and technological advancements. Stakeholders expressed frustration that U.S. companies were unable to export space products that are already available across international markets by companies from allied or partner nations. Updating export controls would provide more revenue for the U.S. commercial sector to sell abroad and compete with other foreign companies to produce better products overall by enabling greater access to global talent and supply chains.

Accelerate the Pace and Alignment of Government Procurement and Acquisition - As the anchor customer for space-related products and platforms, the U.S. Government's timeline for acquisitions sets the pace that commercial sector entities and others must follow. These timelines for acquiring platforms and products are often long, and can be even longer for space platforms and products, due to tightening supply chains, and dominance from defense contractor primes. Therefore, accelerating the pace and alignment of the U.S. DoD's acquisition system needs to focus on the causes of this long process, rather than the symptoms. To increase the pace of government procurement and acquisition of space products and platforms, the Other Transaction Authority should be used more often. Additionally, acquisition and procurement efforts between organizations like the Defense Innovation Unit (DIU), SpaceWerx, USSF Commercial Services Office, USSPACECOM Commercial Integration Office, NSIC, and the OSC should be better organized to meet the demands of rapidly changing technologies.

Implement a Coordinated National Investment Strategy - The United States continues to have an uncoordinated investment approach that relies on small grants across various agencies. While OSTP in the Executive Office of the President serves the critical role of coordinating and providing overall strategic guidance to federal R&D funds for all S&T agencies, the system of investment in the U.S. is highly federated. Treasury, OMB, Commerce, NSF, DoD, DoE, and NASA each make financial injections into the market, but without any coordination or without a roadmap. Going forward, the U.S. Government needs to implement a coordinated national investment strategy that would incorporate the full breadth of grants, debt, equity, derivatives, insurance market, and commodities exchange to catalyze the domestic space economy with minimal duplication of efforts.

LONG-TERM PAYOFF

Develop a Coordinated Space Policy and Regulatory Approach - Stakeholders expressed interest in exploring the establishment of a coordinating body or a Department of Space to coordinate all civilian policy and regulations around space. Examples such as an interagency body like CFIUS could be a better way to regulate the space sector and manage space policy instead of creating a new government entity ad hoc like DHS, which has faced internal organizational problems.[244] A Department of Space or

[244] Stockton, P. and Roberts, P. (2008). Findings from the Forum on Homeland Security After the Bush Administration: Next Steps in Building Unity of Effort. Homeland and Security Affairs Journal; DoE (2023). DoE History | Department of Energy.

similar coordinating regulatory body could internally reinforce the space commercial economy and demonstrate that the U.S. Government has embraced its role as a pace setter for space development. Like DoE, a Department of Space could provide a framework that encompasses a balanced and comprehensive space strategy.[245] Or, like CFIUS, a coordinating interagency body on space regulations and policy could be chaired by one department, similar to how the Department of the Treasury chairs CFIUS, but utilize representatives from across the interagency.[246]

[245] DoE (2023). A Brief History of the Department of Energy.
[246] Treasury (2023). CFIUS Overview | U.S. Department of the Treasury.

Figure 37. Sierra Space team members celebrate the unveiling of the Dream Chaser Tenacity - the first commercial and reusable orbital spaceplane - at the company's Louisville, CO, production facility. (Source: Sierra Space)

SPACE WORKFORCE, STEM & EDUCATION

"The continued growth of the space industry is good news, and that comes with the need for more talent to keep pace with demand."

- HEATHER PRINGLE, Space Foundation[247]

BACKGROUND

The majority of workshop participants emphasized that the space workforce and education pipeline that feeds it are vitally important to U.S. strategic success.

Space Workforce Trends - According to the U.S. Bureau of Labor and Statistics (BLS), baccalaureate careers in aerospace engineering will see a 6% rate of growth over the period 2022 to 2032 - twice the rate of growth for all other occupations.[248] These engineers will earn a median salary of $126,880 per year ($61.00 per hour). Those looking for employment as aerospace operations technologists and technicians, with an associate's degree or equivalent, will see 8% rate of growth over the same period with a median salary of $74,410 per year ($35.78 per hour). The Space Foundation reported an accelerated 3.4% rate of growth in private space employment for the first half of 2023.[235] The United States will need 3,800 new aerospace engineers every year over the next decade to meet this demand[236]. Despite this positive outlook, domestic production of aerospace engineering graduates and certified technicians has slowed in the United States.

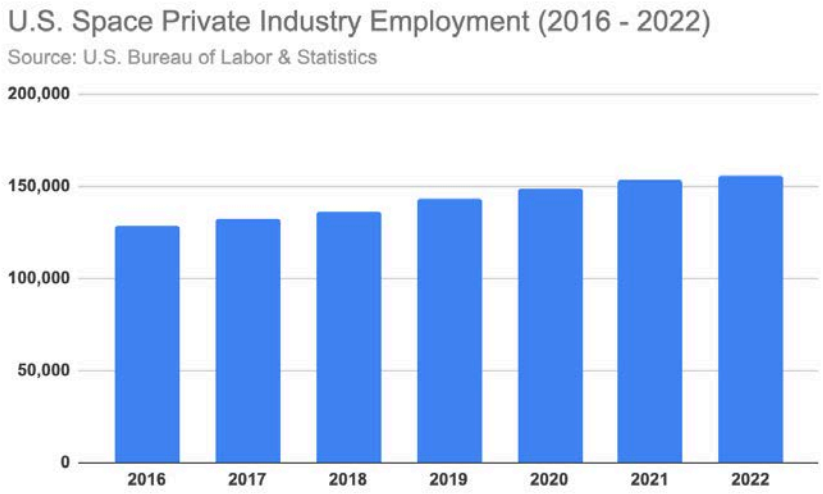

Figure 38. U.S. Space Private Industry Employment 2016 to 2022 (Source: BLS)

[247] Space Foundation (2023). Press Release: Space Foundation Releases the Space Report 2023 Q3.
[248] BLS (2022). Occupational Outlook Handbook: Aerospace Engineering. Bureau of Labor Statistics.

A Competitive Space Employment Market - As the commercial space sector continues to grow, so does the demand for top talent. SpaceX reportedly hires 1 out of every 500 or 0.2% of all applicants[249]. So, where do the rest look for careers? In 2023, the top four most desired workplaces identified by engineering students were all focused on aerospace: (1) Lockheed Martin, (2) SpaceX, (3) Boeing and (4) NASA.[250]

Science, Technology, Engineering, and Mathematics (STEM) education - Over the past year, a combination of NASA and commercial space launches have re-ignited national excitement for STEM education. Private investments successfully delivered the first commercial astronaut mission,[251] tested the first reusable interplanetary transportation system, the first test launch of SpaceX Starship,[252] and drastically increased the size of satellite constellations to support worldwide internet access and terrestrial imagery.[253] Commercial space is opening new avenues for graduates and STEM workers interested in civil, vice defense (or federal) applications.

While these efforts undoubtedly have more of us looking up to the skies, the changing shape of the space ecosystem requires a frank re-assessment of the education and STEM outreach organizations, methods, and financial models currently in place. Unlike the first great space race, today's is driven by a distributed set of players against a nascent and largely invisible set of threats.

Alongside changes to the space economy - the players, the technologies, and the tempo - have been equally disruptive changes to the overall state of work in the U.S. The COVID-19 pandemic has accelerated the adoption of business technologies that support remote and hybrid work. More and more employees are demanding flexible work (both hours and locations), employees are relocating seeking better work-life balance, and the technology sector is still reeling from the effects of hiring sprees and layoffs over the past three years.[254] Higher education is going through its own form of evolution, as well, with everything from student loan forgiveness to on-campus life being challenged. These major shifts each impact the STEM workforce differently, but help tell the story of where we are, how we got here, and where we go next.

The U.S. STEM Workforce has grown and diversified since 2011 - Since our last report, the National Center for Science and Engineering Statistics (NCSES) released their decadal report on Diversity and STEM in the United States.[255] While China is still outpacing the U.S. in overall STEM graduates, the U.S. STEM workforce grew from 29.0 million in 2011 to 34.9 million today; nearly a quarter (24%) of U.S. workers are now employed in STEM fields. Further, the STEM workforce gradually diversified between 2011 and 2021, with increased representation of women and underrepresented minorities—Hispanics or Latinos, Blacks or African Americans, and American Indians or Alaska Natives. While promising, there is still much work to be done. We hope that this

[249] Zippia (2023). How hard is it to get a job at SpaceX?. Zippia.
[250] Universum (2023). Top 100 U.S. employers of engineers. Retrieved from https//:universumglobal.com
[251] Howell, E. (2022). Axiom Space Ax-1 mission: The first all-private crew to the International Space Station. Space.com
[252] Berger, E. (2023). Sorry, doubters: Starship actually had a remarkably successful flight. ArsTechnica.
[253] Ukraine, Starlink
[254] Catalyst (2021). The Great Work/Life Divide in the United States (Report) & Flexible and/or remote work is a top request, new Catalyst-CNBC survey finds.; O'Sullivan, I. (2022). Almost Half of Young Workers Are Burnt Out, Flexibility Can Help. Tech.co; International Labor Organization (2022). Flexible working hours can benefit work-life balance, businesses and productivity; Robinson, B. (2023). Addressing Burnout, Flexible Work And A People-First Work Culture In 2023. Forbes.
[255] National Center for Science and Engineering Statistics (NCES) (2023). Diversity and STEM: Women, Minorities, and Persons with Disabilities 2023. NSF.

report in the context of the space workforce helps spawn both local and national initiatives to proactively foster the growth of a diverse, capable space workforce.

CURRENT STATE

A healthy space infrastructure supported by a strong workforce must be put in place to capture a dominant share of the $1.4 trillion in economic growth expected over the next decade. However, workforce issues threaten the economic viability of space as well as the ability to maintain a strong national security space posture. The Workforce, Education and STEM Working Group has convened for the second year of the State of the Space Industrial Base main conference to address issues identified regarding the lack of a space-ready workforce that would substantially inhibit progress. While much work needs to be accomplished to address the complexity required in building a larger space-STEM and STEAM+ workforce pipeline, momentum to progress STEM workforce development has increased in recent years.

Figure 39. Space Workforce 2030 Participants (Source: SWF2030)

Space Workforce 2030 making strides to redefine the space industry in one year. One year ago, Space Workforce 2030 (SWF2030)[256] sought to lay the groundwork to build the workforce essential for the success of our industry. The SWF2030's bold mission required extraordinary collaboration and commitment from its partners--working together--to build a stronger, more vibrant, and inclusive workforce. Now, per the SWF2030 year-one report,[257] it appears the space industry is making deliberate efforts, and measurable efforts toward the SWF2030 vision--and we could be witnessing a bottom-up approach to actualize the North Star Vision. SWF2030 continues its engagement with the broader space community, seeking partnership opportunities with government, industry, and academia to create a lasting impact on our workforce.

[256] Aerospace (2023). Space Workforce 2030 (SWF2030).
[257] SF2030.org (2023). Space Work Force 2030 Year One Report: Tracking Our Progress To Inspire, Prepare And Employ.

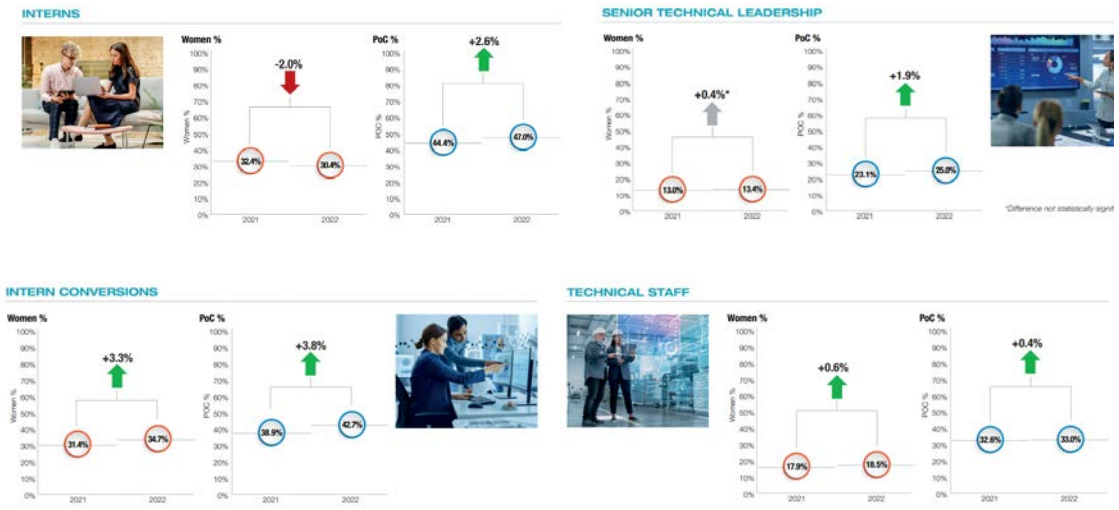

Figure 40. [Top Left to Bottom Right] Intern changes, senior technical leader changes, intern conversions and technical staff changes. (Source: SWF2030)

Ukrainian Conflict - The ongoing Ukrainian conflict has created a real-life laboratory in which to observe and measure the impact of commercial space technologies and the new workforce created to build and sustain them. The most broadly discussed is SpaceX's Starlink constellation. Now consisting of over 3,335 active satellites, with an average of 20 more launching weekly, Starlink offers high-bandwidth internet access to 45 countries.[258] This readily available global access is demonstrating the type of ubiquitous, resilient communications now available to everyone (not just large military powers). In addition to Starlink, Low Earth Orbit (LEO) is also now home to numerous terrestrial imagery providers. Everyone from Maxar to Planet to Umbra now boast commercially available Earth observations. The U.S. space workforce now finds itself supporting these new markets via new roles and services. Engineers and scientists still build and maintain satellites and launch; new sales models for images (both raw data and processed) rely upon business infrastructure, finance, and analysts; political scientists and lawyers advise on the geopolitics of collection and international privacy laws. Nearly anyone can find themselves working in the space sector!

Office of Science and Technology Policy, National Science and Technology Council Releases "Interagency Roadmap to Support Space-Related STEM Education and Workforce[259] - The Roadmap describes the goals and objectives of the Federal departments and agencies represented in the Space STEM Task Force to drive outcomes that bolster the United States (U.S.) capacity to grow, diversify, and strengthen the STEM workforce in response to Vice President Kamala Harris' charge to U.S. space ecosystem stakeholders. The activities put a spotlight on U.S. space efforts and create learning opportunities to inspire people to explore STEM, provide resources and opportunities to better prepare learners for space-related careers, and place a focus on strategies to better support, retain, and advance STEM professionals already in the space STEM workforce, including in the Federal workforce. The roadmap represents the initial coordinated steps that the Federal government can take and will inform future space STEM education and workforce strategy. Implementing this roadmap will advance

[258] The Economist (2023). How Elon Musk's satellites have saved Ukraine and changed warfare.
[259] White House (2022). Interagency Roadmap to Support Space-Related STEM Education and Workforce.

ongoing work and create new opportunities to reach people of all backgrounds and create pathways into space careers for those historically left behind and ensure growth and diversity of the space workforce. This document is consistent with CoSTEM interagency coordination of STEM education programs, investments, and activities and with the National Security Memorandum on Revitalizing America's Foreign Policy and National Security Workforce, Institutions, and Partnerships (NSM-3) issued on February 4, 2021.

Efforts to Attract Skilled Workforce are Still Fragmented and Complex - The working group acknowledged the complexity and fragmented nature of the U.S. STEM ecosystem, making it difficult to achieve a unity of academia, industry & government (AIG). As a result, workforce needs from industry go unmet for multiple reasons, including a lack of graduates and critical skill sets, retention issues and government clearance requirements. Industry has trouble finding space professionals, particularly professionals that have reached mid-career. New graduates and near-retirement professionals are more prevalent but have shortfalls in experience or are looking to retire in the near future respectively. One barrier identified by industry and academia is that government contracts for classified projects require that all full-time employees be cleared at the contract level, even if portions of the work are unclassified. This prevents participation by uncleared interns, students, and junior professionals. In addition, the scarcity of access to mid-level space professionals to mentor junior-level talent makes it harder for junior professionals to progress their careers and contributes to unmet employer needs. Onboarding skilled workers from outside the U.S. also is a major challenge for government space projects, specifically in the DoD, due to over-classification and restrictions from International Traffic in Arms Regulations (ITAR). Classifying authorities within the government appear to be too risk-averse or overstretched when it comes to downgrading or declassifying space projects/programs.

"Last year, 327 Guardians volunteered their time to the STEMtoSpace program and conducted over 680 engagements with more than 48,000 K-12 students around the world, including all 50 states. Digital promotion and social media further boosted those events to an audience of over 14.1 million users online. Let's push those numbers even higher this year!...I encourage all Guardians to participate in the STEMtoSpace program, inspiring K-12 students to pursue STEM education and igniting an interest in the space domain."

- GENERAL CHANCE SALTZMAN, USSF CSO

Figure 41. STEM to Space[260]

[260] Retrieved from https://dafstem.us/event/stemtospace/

KEY ISSUES & CHALLENGES

The key issues and challenges highlighted in the 2023 State of the Space Industrial Base report have been updated/summarized from 2022 to better orient for action. Participants also identified and refined new areas that need to be addressed for the United States to remain at the forefront of space technology development. The obstacles that remain are not technical in nature, but rather regulatory and political. In order for the space industry to reach projected levels in the near and mid-future, a workforce revolution must occur, and it must be led by united efforts across industry, academia, and government.

Marketing Needs Reformation - Traditional marketing falls short with today's youth. The target of space marketing needs to include parents as much as students, and efforts must be demographic appropriate. Participants identified that many outreach programs are lacking in modern marketing techniques and are limited to local and regional efforts. Furthermore, innovation of marketing is complicated as youth-oriented platforms like social media are especially vulnerable to misinformation. There is a lot of information in the world today, and many ways to get it. Space is not tangible; "out of sight, out of mind."

- **Mentoring Must be Addressed** - STEM outreach tends to be grassroots, regional efforts and there is no existing national framework through which to share data, audiences, lessons learned, etc. The U.S. lacks a "whole of government" approach to the challenge, including unreliable or highly disaggregated funding for STEM programs. The lack of influential space and STEM figures in popular culture has had a noticeable effect; U.S. youth are far more interested in becoming YouTubers and influencers than astronauts, the reverse of which is true in China, by a factor of five times.[261]
- **Education** - U.S. students are still largely behind their global peers in STEM education. Students take fewer STEM classes, perform at lower levels, and graduate less prepared for college than elsewhere in the world. Where standards are being lowered to keep children inside the system, students are graduating into university programs that they are ill-prepared for, driving up the dropout rate. Participants noted firsthand experience of students leaving the STEM pipeline due to lack of preparation earlier on. At the same time, the workforce requirements for the exploitation of technology differ from those for the exploration of technology (i.e., trades vs. professions). Prospective students are choosing training and certification incentives over four-year degrees at a traditional college or university.
- **Lack of Meaningful Funding** - The cost of getting a four-year degree is the highest it's ever been. Attaining and maintaining a scholarship through a four-year degree is prohibitively difficult for many students. At the same time, many employers in 'rival' industries offer highly competitive benefits; college tuition, childcare services, and other financial incentives for employees.[262] Industry, civil, and government space organizations need to rewrite legacy hiring processes and "meet the workforce where they are."

[261] Hoffower, H. (2019). Kids in the US and China have starkly different goals, as revealed by a survey that asked them if they'd rather become astronauts or YouTubers. Business Insider.
[262] For example, see Microsoft (2023). Microsoft Employee Perks & Benefits | Levels.fyi

KEY INFLECTION POINTS

There has been an increase in progress towards some of the key inflection points presented in the 2022 State of the Space Industrial Base, with some participants noting one significant negative inflection point:

The U.S. Fails to Reverse the Trend of Decreasing Education Standards - The lowering of standards will have a ripple effect throughout the industry, reducing even further the pool of qualified personnel. At the same time, prospective students and graduates are not motivated to learn the skills required to enter the space industry.

The U.S. succeeds in "meeting people where they are" in removing domestic and international recruitment barriers[263] - Retention is prioritized; incentives, a broadened purview of space, and greater diversity promise a stronger workforce.[264] Easier access to clearances increases available labor pool, and strategic and targeted marketing tell the story of space to different demographics, increasing awareness.

The U.S. fails to reverse the increasing space-related STEM graduate gap with China - This allows China to pull further ahead in R&D investment, manufacturing of critical emergent technologies, and patenting innovative systems. Although China produces more STEM graduates, U.S. workers continue to produce more than 6x productivity than their counterparts. However, our traditional methods of learning and education nonetheless need reform.

The National Space Council launches a North Star Vision with public/private partnership to grow the space workforce – Many critical components of a North Star Vision have made progress in recent times. Roadmaps from government agencies, reports (such as Space Workforce 2030's Year One), and intra-industry efforts have materialized and are actively being implemented. These pieces are paving the way to a "bottom up" approach to a North Star Vision. Much of what remains is directed financial backing to STEM institutions throughout the country.

"The available data on representation of women and people of color makes clear that there is significant room for improvement in our industry in the areas of recruitment, retention, advancement and an overall culture of engagement."

- SPACE WORKFORCE 2030[265]

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[263] White House (2022). FACT SHEET: Biden-Harris Administration Actions to Attract STEM Talent and Strengthen our Economy and Competitiveness.
[264] White House (2022). FACT SHEET: Biden Harris Administration Announces Bold Multi-Sector Actions to Eliminate Systemic Barriers in STEMM | OSTP.
[265] DiMascio, J. (2023). Space Workforce Group Baselines Industry Diversity Stats. Aviation Week.

KEY ACTIONS & RECOMMENDATIONS

These recommendations reflect the numerous inputs from workshop participants and their best assessment regarding which agency(cies) are in the best position to forward the necessary change.

SHORT-TERM PAYOFF

Implement Pathways to the Stars – Create a space workforce pathway spanning early childhood to early career with industry engagement, education provider partnerships, and an emphasis on outreach and support that is more inclusive of diverse populations. Once in place, the intent is to enable other regions to replicate and tailor the program to their region. Key tasks include: mapping nationwide STEM efforts; identifying models to emulate; hosting NASA International Space Apps Challenges, Hackathons, etc. [Note: NASA's International Space Apps Challenges are bigger in Egypt and India than in the U.S.]. Many industry companies have outreach programs that are sponsored locally, but much of the nation is left unaddressed. Other recommendations actions: identify models to emulate; engage and understand the reach of existing organizations; engage industry locally and identify 'STEM deserts' in the country. Rather than reinvent programs, try connecting them. Leverage workforce efforts such as Space Workforce 2030 and other industry organizations; and develop mentorship models with incentives for industry to engage throughout education and a talent pipeline.

Establish strategic messaging and marketing. Create a language and methods to meet the workforce (and students) where they are. Use new techniques to engage children; conduct focus groups; social media, etc. Get on screens. Create strategic messaging at a national level that can be used by all regions and sectors of the industry to showcase the full range of job opportunities in space, highlighting past successes from individuals of diverse backgrounds in space careers and achievements to showcase the full range of job opportunities, excitement and open access to all for space. Reach kids early and excite beyond STEM. Space is more than just engineering. Look at opportunities to transition the existing workforce towards the space industry. Develop platforms that reach kids ages 6 to 10, such as PBS shows, focus groups, Khan Academy, social media marketing, National Space Day, podcast and influencers.

MID-TERM PAYOFF

Aligned Space-STEM North Star Vision: Support of Implementation of Interagency Roadmap to Support Space-Related STEM Education and Workforce[266] - Addressing the complexity and fragmentation of space-STEM and STEAM+ educational systems requires "centralized planning and, decentralized execution." A recent report by the Committee on STEM Education of the National Science & Technology Council,[267] echoed by NASA, DoE and the Department of Education[268] and for which OSTP has released a progress report detailing the work-to-date of interagency working groups.[269]

[266] Committee on STEM Education, National Science & Technology Council. (2018). Charting a Course for Success: America's Strategy for STEM Education. U.S. Government.
[267] Ibid.
[268] NASA (2018). Charting a course for success: america's strategy for stem education.; DoE (2022). Charting a Course for Success: America's Strategy for STEM Education.; Dept of Education (2018). Charting a Course for Success: America's Strategy for STEM Education. A Report by the Committee on STEM Education of the National Science & Technology Council.
[269] White House (2021). Progress Report on the Implementation of the Federal STEM Education Strategic Plan.

Will the Interagency Roadmap and the team formed be able to support the idea of a North Star Vision for space workforce? Perhaps the more deliberate efforts from the space industry, specifically the Space Workforce 2030 effort, will be a more grass roots effort that implements a bottoms-up approach that leads to a national North Star Vision for STEM and space workforce growth. Whole-of-nation STEM workforce development strategies can be executed at the local level to match the needs of the thousands of diverse communities around the country in order to maximize recruitment and retention in space-STEM fields.

Assess and address funding gaps/engagement models as a coordinated nationwide effort. Act on the findings of Pathway to the Stars. Work with professional societies and 501c3s. Look at NASA pass-through options. Examine opportunities with the Space Force Association? Match the desired outcomes in increasing the size of the space workforce in alignment with national security, commercialization and sustainability imperatives. Assess and address funding gaps/engagement models (i.e., AFA and Cyber Patriot, NASA Space Apps challenge). Identify gaps/places where it needs bolstering, reach into industry networks to support with funding, resources, etc. Approach Space Force Association to take on this role similar to AFA for aviation; National Space Society; programs such as, HAM Radio, Girl Scouts, model rocket clubs, Teachers-in-Space, Starbase, Club for the Future.

LONG-TERM PAYOFF

Salaries / Recruitment / Retention of STEM Workforce. Assess incentive structures, commercial versus military/government pay, recruitment, incentives, retention. Develop a Space ROTC similar to other military ROTC programs. Look at programs such as the Defense Civilian Training Corp.

Scale Pathways to the Stars Program – With whole-of-nation STEM workforce development strategies in place, the Pathways to the Stars program can be replicated in different regions and scale successes from the pilot program.

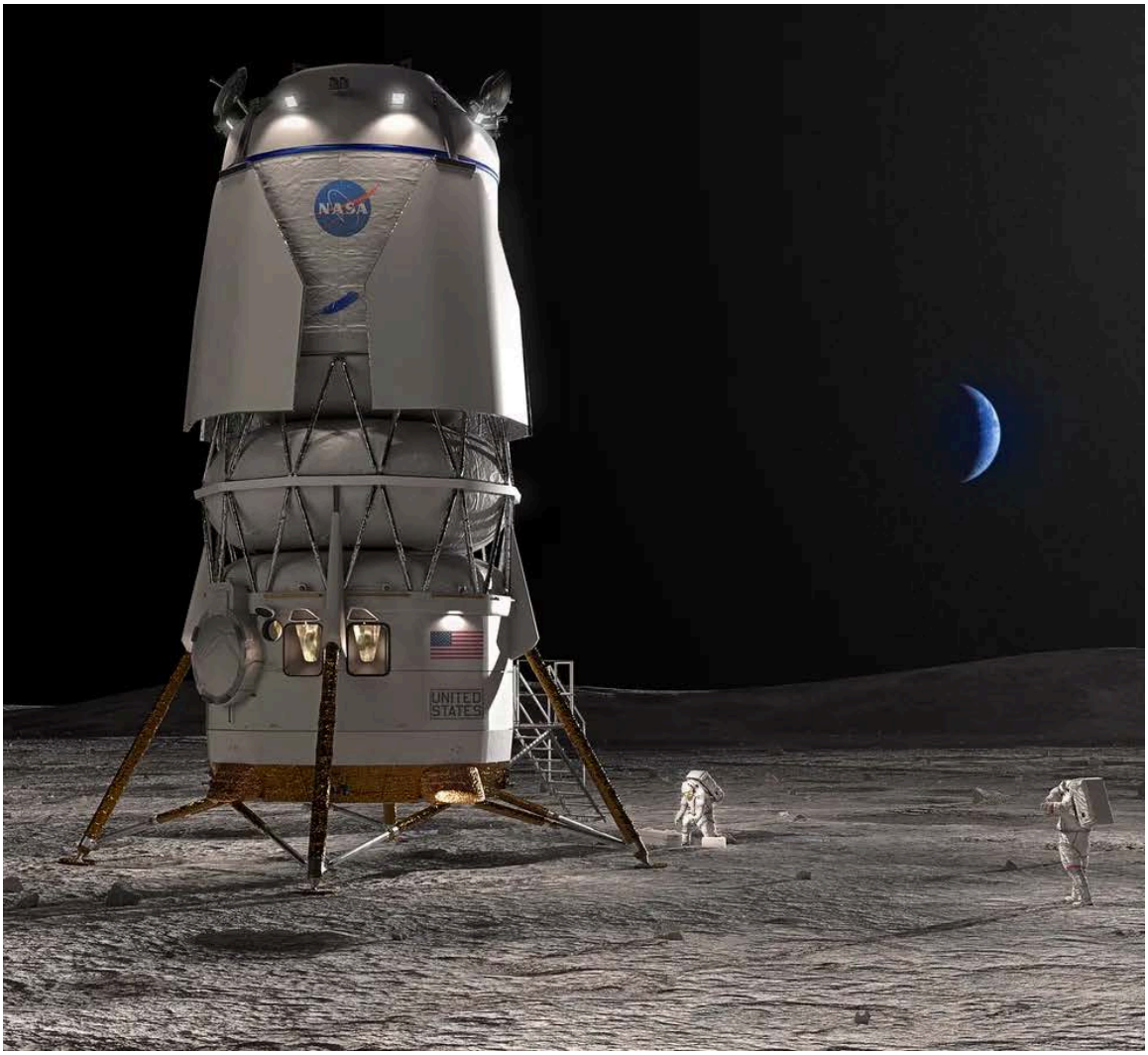

Figure 42. A rendering of Blue Origin's Blue Moon lander that will return astronauts to the Moon as part of NASA's Artemis program. (Credit: Blue Origin)

EPILOGUE:
2013 OUTLOOK vs. 2023 REALITY

Figure 43. Galaxy M51 imaged with the James Webb Space Telescope mid-infrared instrument. (Credit: NASA)

"Never bet against America." [270]

- WARREN BUFFETT, Chairman, Berkshire Hathaway

As the year 2023 comes to a close, it is habitual to think about the past year with a focus on all that has been accomplished, and all that remains to be done. With respect to the commercial space sector, it is even more rewarding to expand the aperture of time and consider all the gains achieved over the past ten years. Simply put, this has been an extraordinary decade of commercial growth and transformation with the engine of innovation strongly favoring commercial - not government - advancements in launch vehicles and proliferated satellite constellations providing low cost, global communications, remote sensing and other services creating new jobs and greater contribution to the gross domestic product.

Retrospectively, the year 2013 doesn't seem to have been that long ago. Upon reflection, it was a fabulous year for spaceflight achievements: the Voyager 1 spacecraft became the first man-made machine to exit the solar system, Orbital Sciences successfully delivered its first Cygnus commercial cargo resupply mission to the International Space Station, SpaceX launched its first commercial mission supporting a private customer, and Canadian Astronaut Chris Hadfield recorded Space Oddity by David Bowie in the microgravity environment of space garnering 53 million views on YouTube.[271] While we can look back fondly upon the past decade with a great sense of achievement, it's important to note that the 'thought leaders' in 2013 were much less optimistic looking forward to 2023.

In 2013, the Russian Federation performed more orbital launches (33) than any other country including the U.S. (19), China (15) and Europe (4).[272] In fact, the U.S. only performed 6 orbital launches that year, and the price per kilogram to low Earth orbit ranged from $10,600 to $34,500.[273]

[270] Buffett, W. (2021). Letter to Shareholders. Berkshire Hathaway.
[271] Knapp, A. (2013). Eleven Great Space Moments Of 2013. Forbes.
[272] Krebs, G (2023). Orbital Launches of 2013. Gunter's Space Page.
[273] CSIS Aerospace Security Project. (2022). Cost of space launches to low earth orbit. CSIS.

China secretly conducted an anti-satellite missile test of the Dong Ning-2.[274] And just two years earlier, the Space Shuttle had been retired, forcing NASA to fly astronauts to the International Space Station as paying passengers aboard the Russian Soyuz spacecraft. Understandably, the U.S. space future seemed bleak. However, entrepreneurs and their early investors were already working hard to disrupt the status quo.

The Commercial Space Transportation Forecasts Report produced by the FAA in 2013 included a near flatline forecast of non-geosynchronous orbit (NGSO) commercial launches through 2022 with inputs from both government and commercial satellite operators and launch providers (see Figure 42).[275]

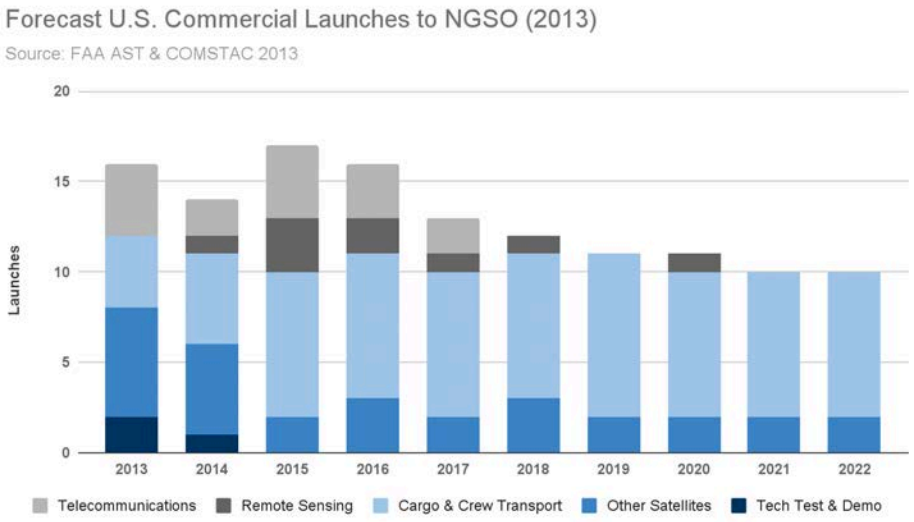

Figure 44. FAA's rather conservative forecast of commercial space launches in 2013 (Credit: DIU)

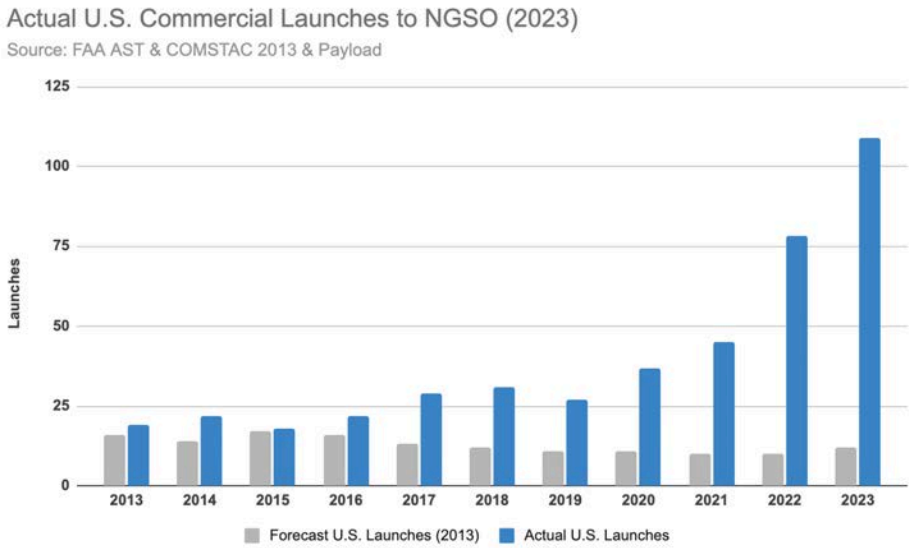

Figure 45. Comparison of FAA's forecast 2013 (above) to what actually transpired over the past decade. Private investment and commercial innovation resulted in an unforeseen hockey stick (Credit: FAA/BryceTech)

[274] Keck, Z. (2014). China Secretly Tested an Anti-Satellite Missile. The Diplomat.
[275] FAA (2013). The Annual Compendium of Commercial Space Transportation 2013.

While these forecasts gathered dust on book shelves, venture capital investment combined with decisive action to commercialize cargo resupply and crew services by NASA fueled a revolution in space operations that re-establish American leadership in space to the benefit of the commercial, civil, military and allied space communities.

American dynamism ALWAYS outperforms the skeptics and the bureaucratic group-think that seeks to temper dreams and lower expectations. Perhaps this alone may be the most important observation in this SSIB'23 report. How far we have come as a spacefaring society and how short sighted the experts were about the decade ahead of us in 2013 is noteworthy as we posture for the next decade ahead of us.

So why be pessimistic about the future?

It is only fitting that NASA released its Moon to Mars Strategy in 2023[276] which includes commercial and civil space working together on a sustainable architecture that will enable the long-term exploration and settlement of the Moon, then Mars, and then the journey beyond for the benefit of all humanity. Our first steps begin tomorrow and that is why we must maintain this momentum and reach our true potential.

"Every vision is a joke until the first man accomplishes it; once realized, it becomes commonplace."[277]

- ROBERT H. GODDARD

☆ ☆ ☆

[276] NASA (2023). NASA Details Strategy Behind Blueprint for Moon to Mars Exploration.
[277] Robert Goddard's response to a reporter's question following criticism in The New York Times, 1920.

"I was writing up my notes from the SSIB and a resounding theme emerged: it's the only honest discussion of the problems between acquisition and tech development that I can think of. Academia can't be that honest because it has to be novel. Advisory boards are largely for show. The SSIB condition Chatham house rules produces genuine conversation where gov people don't just sit there and defend stupid positions. Everyone kinda has to be reckoned with the issues and do their best on some solutions. It's partly why the solutions are never great, but the problems hit the mark and describe the conditions we're in. Therefore the problem diagnosis gives me hope, because it's clear what solutions are a waste of time. It's gonna take a while to think through what we can do about the challenges, and where to start. But I feel like I learned a ton last week, and really appreciate being invited to participate. It puts me in the position of "strategic solver" for the time being."

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APPENDIX A

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Richman, Heather, Silicon Valley Defense/BMNT
Rosenthal, Steve, Loeb & Loeb
Ryals, Deanna, USSF SSC/IA
Shimmin, Rogan, DIU
Shiue, Minpo (Po), SSC/BZ
Simon, Sarah, SSC/IA
Sugai, Hiroyuki, Japanese Embassy, Washington DC
Tedman, Paul, USSPACECOM
Trojahn, Frank, Danish Navy
Warmerdam, Peter, British Embassy
Worden, Pete, Breakthrough Initiatives

Virtual

Cantiello , Maurizio , Italian Embassy, Washington DC
Attridge, Jeremy (Jez), UK Embassy, Washington DC
Kolesnikov-Lindsey, Rachel, SSC/IA
Nuno, George, HQ USSF
Garretson, Peter, AFRL

APPENDIX B

PREVIOUS REPORTS

Preparing for the Possible Futures of 2040: Junior Workforce Perspective

Report on the Space Futures Workshop 1A

8 Aug 2023

Distribution D:
Authorized to the Department of Defense and U.S. DoD contractors only

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Commercial Planning Assumptions for The United States Space Force:
Findings from the Space Futures Workshop with Industry

24 Mar 2023

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Approved for Public Release. Distribution Unlimited.

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State of the Space Industrial Base 2022
Winning the New Space Race for Sustainability, Prosperity and the Planet

August 2022

Distribution A:
Approved for Public Release. Distribution Unlimited.

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State of the Space Industrial Base 2021
Infrastructure & Services for Economic Growth & National Security

October 2021

Distribution A:
Approved for Public Release. Distribution Unlimited.

Defining the Road to 2035-45 USSF Capabilities
Report on the USSF Space Futures Workshop 2a

5 Aug 2021

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State of the Space Industrial Base 2020
A Time for Action to Sustain U.S. Economic & Military Leadership in Space

July 2020

Distribution A:
Approved for Public Release. Distribution Unlimited.

Download

The Future of Space 2060 & Implications for U.S. Strategy
Report on the Space Futures Workshop

5 Sep 2019

Distribution A:
Approved for Public Release. Distribution Unlimited.

Download

State of the Space Industrial Base: Threats, Challenges and Actions
A Workshop to Address Challenges and Threats to the U.S. Space Industrial Base and Space Dominance

30 May 2019

Distribution A:
Approved for Public Release. Distribution Unlimited.

Space Power Competition in 2060: Challenges and Opportunities
Report on the Space Futures Workshop 1A

9 Mar 2019

Distribution D:
Authorized to the Department of Defense and U.S. DoD contractors only

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APPENDIX C

KEY ACTIONS & RECOMMENDATIONS FROM SSIB'22 REVISITED

ASSESSING 2022 KEY ACTIONS & RECOMMENDATIONS

What progress has been made toward last year's SSIB recommendations?

Establish an enduring U.S. North Star Vision for Space as an essential guidepost to sustain the United States' competitive advantage against a rapidly advancing China that is now collaborating with Russia. This vision must be as clear and ambitious in scale and timeline as the PRC and more inclusive of international collaboration across the spectrum of commercial, civil and national security space activities. For the first time, participants expressed concerns that China appears to be on track to surpass the U.S. as the dominant space power by 2045 or potentially earlier unless proactive measures are taken now to sustain our nation's leadership.

- UPDATE: While the U.S. has yet to provide a consolidated North Star Vision for Space, the Administration (and especially OSTP) has enhanced the clarity of U.S. purpose through the release of multiple policy documents including the National Cislunar S&T Strategy, LEO R&D Strategy, ISAM implementation plan.

Enable National Security Priority Processing of Licenses/Environmental Clearances for Critical Space Systems. The agile engineering ecosystem that has become the hallmark of the new space era is at risk due to U.S. policy and procurement practices put in place by Robert McNamara in 1962 when the government was the source of innovation leadership. Today, we must use Defense Production Act (DPA) Title III and other authorities such as the Defense Priorities and Allocation System (DPAS) to reduce bureaucratic delay on critical needs for national security.

- UPDATE: No Progress

Elevate the Office of Space Commerce (OSC) to report directly to the Secretary of Commerce. In a whole-of-nation strategy where commerce and economic growth are central to strategic competition, the OSC cannot be buried under our weather service. The White House and Congress should elevate the office by FY24.

- UPDATE: No progress. OSC remains too subordinate, too small in both staff and budget to execute national strategic objectives.

DoD requires a process to rapidly acquire and constitute commercially-sourced capabilities for U.S. and allied warfighters. Commercial space technology has forever changed the nature of conflict as evidenced by its contribution to the defense of Ukraine. Remote sensing, advanced analytics, and broadband communications are just a few of the tactical solutions that have had strategic impact on Russia's war in Ukraine.

- UPDATE: The Space Force opened the Commercial Space Office (COMSO) in June 2023 to maximize and optimize opportunities for commercial collaboration in its race to resilience by 2026 (See Figure C-1).[278]

[278] Kane, L. (2023). Commercial Space Office Brings Unity of Effort to Industry Collaboration. SSC Public Affairs

Figure C-1. USSF leaders cut the ribbon opening the Commercial Space Marketplace for Innovation and Collaboration (COSMIC) in Chantilly, VA. (Credit: U.S. Air Force photo by Cherie Cullen)

In order to save the planet, we must get off-planet. Advancements in off-world power production, manufacturing, and Lunar resource extraction will be foundational to the future multi-trillion-dollar space economy. In order to lead, enabling strategy, policy, and law is required. Activities and human presence in space should be driven by an international rules-based order and systems that uphold liberty and prosperity for all humankind.

- UPDATE: There has been significant progress since last year. The White House released the first-ever Cislunar Strategy, NASA released its Moon to Mars Objectives and Development, DARPA began work via LunA-10 to catalyze a Lunar economy in 10 years. The Administration significantly grew the number of Artemis partners interested in a rules-based order.

We must accelerate progress on strengthening the space industrial base. The pace of progress towards past recommendations has not been brisk enough to lead. We must catalyze domestic manufacturing and supply chains to reduce costs and lead times while making headway on recommendations from previous years' SSIB recommendation.

- UPDATE: The nation took a number of steps. It elevated the status of the Defense Innovation Unit to a direct report to the Secretary of Defense, established the Office of Strategic Capital, and placed new emphasis on the industrial base in the National Defense Strategy. NASA vision documents such as the Moon-to-Mars Objectives recognize the importance of an in-space industrial base and self-sustaining economy. DARPA has begun efforts to create an in-space industrial base. The Space Force, AFRL and SpaceWERX accelerated on-orbit service efforts via Orbit Prime. The Space Force established its Commercial Space Office.

APPENDIX D

SSIB'22 PARTICIPANTS SURVEY AND RESULTS

We asked participants to rank-order the key actions and recommendations from the 2022 report in terms of impact and urgency.

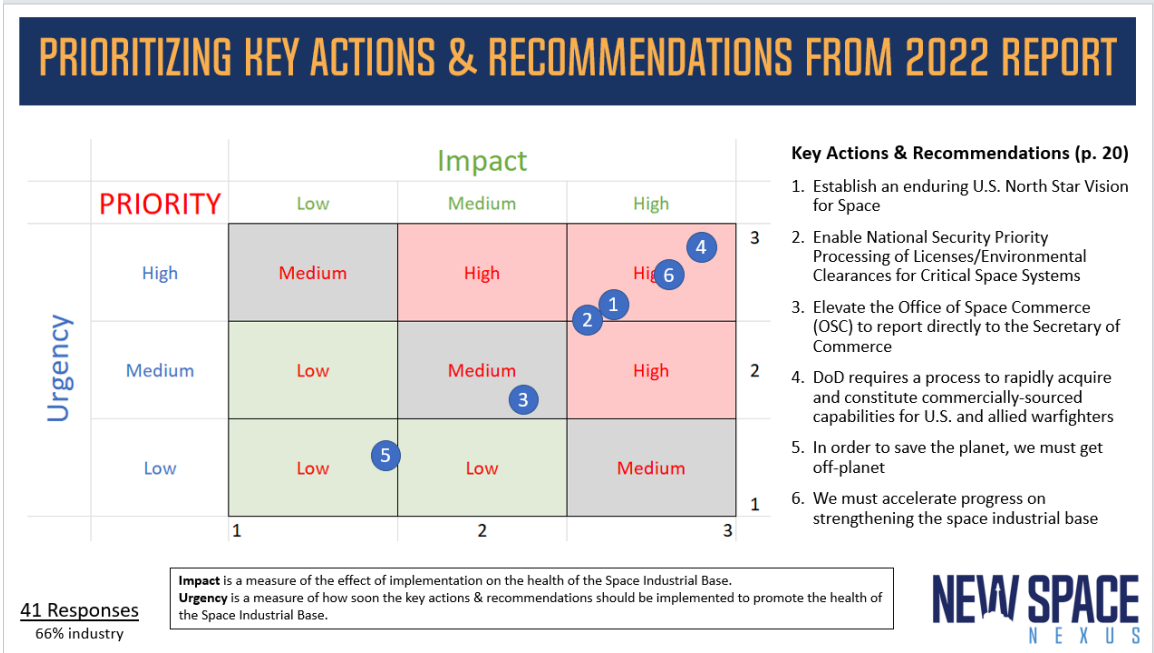

Figure D-1. SSIB 2022 Recommendation Priorities. (Credit: NewSpace Nexus)

This year's participants identified a clear order regarding the current urgency of action:

- DoD requires a process to rapidly acquire and constitute commercially-sourced capabilities for U.S. and allied warfighters (#4)
- We must accelerate progress on strengthening the space industrial base (#6)
- Establish an enduring U.S. North Star Vision for Space (#1)
- Enable National Security Priority Processing of Licenses/Environmental Clearances for Critical Space Systems (#2)
- Elevate the Office of Space Commerce (OSC) to report directly to the Secretary of Commerce (#3)
- In order to save the planet, we must get off-planet (#5)

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APPENDIX E

ACRONYMS & ABBREVIATIONS

3GPP – 3rd Generation Partnership Project
5G – Fifth Generation Wireless Internet
ADR –Active Debris Removal
AFA –Air & Space Forces Association
AFRL – Air Force Research Lab
AFRL/RV – Air Force Research Lab Space Vehicles Directorate
AI – Artificial Intelligence
AI/ML – Artificial Intelligence/Machine Learning
AIG– academia, industry & government
AMC –Air Mobility Command
AUKUS – Australia, the United Kingdom, and the United States (trilateral security pact)
BAA – Broad Agency Announcement
BIS – Bureau of Industry and Security (DoC)
BMC3 – Battle Management, Command, Control, and Communications
CAGR – Compound Annual Growth Rate
CAPSTONE – Cislunar Autonomous Positioning System Technology Operations and Navigation Experiment [NASA]
CASR – Commercial Augmented Space Reserves
CDOL –Contested, Degraded, Operationally Limited
CFIUS – Committee on Foreign Investment in the United States
CISA – Cybersecurity and Infrastructure Security Agency
CIC – Commercial Integration Cell
CJADC2 – Combined Joint All Domain Command & Control
CLPS – Commercial Lunar Payload Services (NASA)
CMMC – Cybersecurity Maturity Model Certification
COMSO – Commercial Services Office (under USSF/SSC)
CONFERS – Consortium for Execution of Rendezvous and Servicing Operations
COVID – Coronavirus Disease
COSMIC– COnsortium for Space Mobility and ISAM Capabilities
COTS – Commercial Orbital Transportation Services
CR – Continuing Resolution
CSCO – Commercial Satellite Communications Office (USSF)
CSO – Commercial Solutions Openings [DIU]
CSO – Chief of Space Operations [USSF]
CSET – Center for Security and Emerging Technology
CSPO –Commercial Systems Program Office (NRO)
CSPoC –Combined Space Operations Center
CRADA - Cooperative Research and Development Agreement
CUI –Controlled Unclassified Information
CYBERCOM – Cyber Command
DARPA – Defense Advanced Research Projects Agency [DoD]
DDTC – Direct Commercial Sales
DDTC – Directorate of Defense Trade Controls [DoS]
DHS – Department of Homeland Security
DIU – Defense Innovation Unit [DoD]
DoC – Department of Commerce
DoD – Department of Defense
DoE – Department of Energy
DoS – Department of State
DoT – Department of Transportation
DPA – Defense Production Act
DPAS – Defense Priorities and Allocation System
DRACO – Demonstration Rocket for Agile Cislunar Operations (DARPA)
DSCA – Defense Security Cooperation Agency
DSO – Dynamic Space Operations
EO – Electro Optical
EO – Executive Order [White House]
EOCL – Electro-Optical Commercial Layer

EOP – Executive Office of the President
EULA – End User License Agreement
ExIm – Export Import Bank
FAA – Federal Aviation Administration [DoT]
FAO – Foreign Area Officer
FCC – Federal Communication Commission
FCT –Foreign Comparative Test
FMS – Foreign Military Sales
FY – Fiscal Year
FYDP – Future Years Defense Program
GAO – General Accounting Office
GEO – Geostationary Earth Orbit
GEOS – Geostationary Operational Environmental Satellites
HALEU –High-Assay Low-Enriched Uranium
HSA – Hybrid Space Architecture
IA – International Affairs Offices
IARPA – Intelligence Advanced Projects Agency
IC – Intelligence Community
ICAM – Identity Credentialing and Access Management
IDIQ – Indefinite Delivery, Indefinite Quantity.
IRS –Internal Revenue Service
ISAM – In-Space Servicing Assembly and Manufacturing
ISRU – In-Situ Resource Utilization
ISS – International Space Station
ISWG – Interagency Spaceport Working Group
ITAR – International Trafficking in Arms Regulation
ITAR/EAR – International Trafficking in Arms Regulation or Export Administration Regulations
JADC2 – Joint All Domain Command and Control
JETSON – Joint Energy Technology Supplying On-Orbit Nuclear
JPSS – Joint Polar Satellite System
kWe – Kilowatt-electric
LINUSS –Lockheed Martin's In-space Upgrade Satellite System
LEO – Low Earth Orbit
MEO – Middle Earth Orbit
MEV – Mission Extension Vehicle
MMH–mono-methyl hydrazine
MOA–Memorandum of Agreement
MRV – Mission Robotic Vehicle
MW – Megawatt
NAPP – Nuclear Advanced Propulsion and Power
NASA – National Aeronautics and Space Agency
NATO – North Atlantic Treaty Organization
NCSES – National Center for Science and Engineering Statistics
NDAA – National Defense Authorization Act
NDSA – National Defense Space Architecture
NESDIS – National Environmental Satellite Data and Information Service
NGSO – non-geosynchronous orbit
NISPOM – National Industrial Security Program Operating Manual
NOAA – National Oceanic and Atmospheric Agency [DoC]
NRO – National Reconnaissance Organization [DoD]
NRO/CSPO – National Reconnaissance Organization Commercial Systems Program Office [DoD]
NSA – National Security Agency
NSC – National Security Council [EOP]
NSF – National Science Foundation
NSIC – National Security Innovation Capital [DoD]
NSM – National Security Memorandum
NSpC – National Space Council [EOP]
NTIB – National Technology and Industrial Base
NTN – Non Terrestrial Networks
NTO – Di-Nitrogen Tetroxide
O&M – Operations & Maintenance
ODNI – Office of the Director of National Intelligence
OIG – Office of Inspector General [NASA]
OISL – Optical Intersatellite Link
OMB – Office of Management and Budget [EOP]
OODA – Observe Orient Decide Act
OPR – Office of Primary Responsibility
OSAM – On-Orbit Servicing Assembly and Manufacturing

OSC – Office of Strategic Capital [DoD]
OSC – Office of Space Commerce [DoC]
OSD – Office of the Secretary of Defense [DoD]
OSTP – Office of Science and Technology Policy [EOP]
OTA – Other Transaction Authority
OUSD R&E – Office of the Undersecretary of Defense for Research and Engineering
PIC – Program Integration Council
PNT – Precision Navigation & Timing
PPBE – Planning, Programming, and Budgeting & Execution
PRC – People's Republic of China
PWSA – Proliferated Warfighter Space Architecture
QoS –Quality of Service
R&D – Research and Development
RDT&E – Research Development Test and Evaluation
RF – Radio Frequency
RFP – Request for Proposal
ROTC – Reserve Officer Training Corps
RPS – Radioisotope Power Systems
RPOD – Rendezvous, Proximity Operations, and Docking
RTG – Radioisotope Thermoelectric Generators
SAF/IA – Office of the Assistant Secretary of the Air Force for International Affairs
S&T – Science and Technology
SA – Situational Awareness
SAF/IA – Assistant Secretary of the Air Force for International Affairs
SAF/SQ – Office of the Assistant Secretary for Space Acquisition and Integration
SAR – Synthetic Aperture Radar
SATCOM – Satellite Communications
SBIR – Small Business Innovative Research
SBSP – Space Based Solar Power (renewable energy source)
SDA – Space Development Agency
SDA – Space Domain Awareness
SMFC – Space Mobility Field Command [Notional]
SNAP-10A – System for Nuclear Auxiliary Power
SPAC – Special Purpose Acquisition Corporation
SpaceX – Space Exploration Technologies (company)
SPD –Space Policy Directive [White House National Space Council]
SSA – Space Situational Awareness
SSC – Space Systems Command [USSF]
SSC/CSCO – Space Systems Command Commercial Satellite Communications Office[USSF]
SSIB – State of the Space Industrial Base (report)
STEAM – Science, Technology, Engineering, Arts and Mathematics
STEM – Science Technology Engineering and Math
STM – Space Traffic Management
STTR – Small Business Technology Transfer
SVDG – Silicon Valley Defense Group
SWF – Space Work Force
TCP/IP – Transmission Control Protocol/Internet Protocol
TCPED – tasking, collection, processing, exploitation, and dissemination tasking, collection, processing, exploitation and dissemination
TSA –Technology Safeguard Agreement
U.S. – United States
UK – United Kingdom
UKR – Ukraine
USA – United States of America
USAF – United States Air Force
USCG – United States Coast Guard
USG – United States Government
USML – United States Munitions List
USSF – United States Space Force [DoD]
USSPACECOM – United States Space Command [DoD]
USSOCOM – United States Special Operations Command
VICTUS NOX – 'conquer the night' [DoD responsive launch mission]
xGEO – Beyond Geostationary Orbit
YoY – Year-over-Year
Yr – Year

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