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SCIENCE AND TECHNOLOGY POLICY OFFICE

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In-space Servicing, Assembly and Manufacturing (ISAM) National Strategy Implementation Plan	)	87 FR 26377

COMMENTS OF ASTROSCALE U.S. INC.

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I. Introduction

Astroscale U.S. ("Astroscale") is pleased to provide comments into the Office of Science and Technology Policy (OSTP)'s Request for Comment regarding the In-space Servicing, Assembly and Manufacturing (ISAM) National Strategy (hereafter the "National Strategy" or "the Strategy"). We thank the Office and the Working Group for their continued dedication to realizing the manifold benefits of ISAM capabilities for current and future activities across the U.S. space enterprise.

Astroscale's mission is to secure the safe and sustainable development of space for the benefit of future generations. Through the creation of technologies, advancement of business cases, and contributions to inform sustainable policy, Astroscale is shifting the course of space operations away from the status quo 'throwaway' culture towards a 'servicing culture' and broader paradigm of stewardship of the space environment.

ISAM capabilities advance and enable increasingly ambitious human endeavors in spaceflight and space science. From Earth orbit to cislunar and interplanetary missions, the applications of ISAM technologies and practices support the development of a vibrant space ecosystem. The constraints of contemporary methodologies—for example, the need for spacecraft to carry reserve fuel, retain redundant components, integrate onto a single launch vehicle, and the need for operators to weigh the financial impact of expending fuel for maneuvers in orbit—are limitations that can ISAM services will discharge as they grow more efficient, routine, and cost-effective. As the demand for space services, data, and structures that can support scientific objectives continues to grow, the application of ISAM technologies stand to revolutionize space operations across civil, national security, and commercial space sectors.

The National Strategy[1] outlines strategic goals to shape the United States government's national approach in advancing ISAM capability development, building on existing and emerging investments and activities across the U.S. government, industry, and academia. These goals address challenges currently impeding the development of the ISAM industry. Coupled with implementation of the Orbital Debris Research and Development (R&D) Plan,[2] implementation of the Strategy will generate cross-cutting advancements to space operations and architectures, bolstering their efficiency, utility, flexibility, and value across government and commercial applications.

Enhanced interagency coordination to clarify regulatory and procurement authorities, harmonize funding and architecture planning, and streamline regulatory oversight and continuing supervision over commercial ISAM capabilities are necessary to bolster the U.S. commercial ISAM industry's global competitiveness. This clarity and synchronization of interagency priorities and needs will ensure that the sustained investments it undertakes in R&D for ISAM capabilities across civil and defense space architectures will benefit stakeholders across the entire U.S. space industrial base.

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[1] IN-SPACE SERVICING, ASSEMBLY, & MANUFACTURING INTERAGENCY WORKING GRP., NAT'L SCI. & TECH. COUNCIL, IN-SPACE SERVICING, ASSEMBLY, AND MANUFACTURING NATIONAL STRATEGY (Apr. 2022) [*hereinafter* National Strategy or Strategy]. https://www.whitehouse.gov/wp-content/uploads/2022/04/04-2022-ISAM-National-Strategy-Final.pdf

[2] ORBITAL DEBRIS RES. & DEV. INTERAGENCY WORKING GRP., NAT'L SCI. & TECH. COUNCIL, NATIONAL ORBITAL DEBRIS RESEARCH AND DEVELOPMENT PLAN (Jan. 2021)

Finally, collaboration to implement the Strategy with likeminded allies, international partners, industry consortia and standards organizations, and other global stakeholders is critical to the full execution of U.S. strategic space policy priorities.[3]

In-space servicing, assembly, and manufacturing capabilities offer tools to preserve and enhance U.S. global leadership in furthering the responsible, peaceful, and sustainable use of outer space. As they reach maturity, they will redefine the art of the possible and render contemporary constraints on mission and system design, reliability, and other factors that reduce mission success in space operations obsolete. Astroscale welcomes this opportunity to provide our suggestions for how the United States government can aid in the realization of this future.

II. What specific technologies and capabilities require priority R&D focus to enable and advance the development of a suite of commercial ISAM capabilities over the next 10-15 years?

The United States government should prioritize research and development in autonomy, sensors, interfaces, detumbling methods, and modularity to advance the development of a suite of commercial ISAM capabilities over the next ten to fifteen years.

A comprehensive U.S. government commitment to the research and development of ISAM capabilities that effectively leverages commercial innovation in support of current and future interagency needs is critical to the sustained accessibility and resiliency of operations in the space domain. Despite our economic and national security reliance upon space systems, the majority of spacecraft today are designed to be inefficiently discarded as soon as they reach their end-of-mission, leaving gaps in mission continuity and compounding the risks of harmful orbital debris generation in strategically advantageous orbital regimes. Fully realized ISAM capabilities extend the value, efficiency and operational lifetime of current space systems which may otherwise be difficult and costly to replace expeditiously while also facilitating the mitigation and remediation of orbital debris.

In the past decade, several commercial developers of ISAM technologies have demonstrated successes, but the U.S. government has yet to holistically evaluate how it can incorporate these capabilities into its future space system architectures.

A barrier to civil and defense stakeholders' ability to become a customer of U.S. commercial ISAM services and support an in-space servicing ecosystem is the lack of adequate and consistently appropriated funds for the research, development, and deployment of technologies, tools, and methods that function as basic building blocks underpinning the broad range of commercial ISAM services coming to market. Key areas for near- and long-term R&D investment are as follows:

A. Short-Term R&D Priorities

1. Autonomy

For ISAM applications that require rendezvous, proximity operations, and docking (RPOD) with client space systems, the ability to autonomously conduct servicing operations with minimal human-in-the-loop intervention is a major factor in the safety, efficiency, and cost-effectiveness of providing commercial services. Further research is needed in the application of machine learning to automate onboard data processing and to mitigate the challenges to computing posed by the harsh space environment without

[3] EXEC. OFFICE OF THE PRESIDENT, UNITED STATES SPACE PRIORITIES FRAMEWORK (Dec. 2021). https://www.whitehouse.gov/wp-content/uploads/2021/12/United-States-Space-Priorities-Framework-_-December-1-2021.pdf

imposing prohibitively high weight and costs of traditional radiation hardening and shielding techniques. Increased testing and flight demonstration opportunities are needed to further validate and augment simulations and training datasets for imaging and pose estimation, vision processing, ranging, bearing, positioning, and docking algorithms with real-world data.

2. Sensors and Sensing Techniques

The quality of sensors that are ideal for RPOD applications in most ISAM activities often fall into a 'middle ground,' where typical commercial spacecraft sensors are often insufficient on their own, but bespoke solutions can be either prohibitively expensive or custom-built for other use cases, such as for advanced science instruments. Research is needed to explore the utility of adapting terrestrial sensors and tools into space-rated hardware for use in ISAM operations, and the U.S. government should work to offset the costs of high-quality sensor suites that could be applied to RPOD use cases. Beyond that, the U.S. government should partner with industry and academia to evolve sensing modalities and techniques utilized for RPOD and servicing, encompassing hardware, algorithms for specific approach types and services, and onboard processing, to generate new systematic approaches to in-space servicing.

3. Interfaces

Development and adoption of common servicing interfaces, including for docking, refueling, power, and data connections will act as ground-level infrastructure that will enable the industry to design and deliver routine ISAM services at scale. Akin to the standardized adoption of tow hitches for varying classes of terrestrial vehicles, spurring the development, adoption, standardization of 'lowest common denominator' servicing interfaces that can be utilized for a range of consensual commercial ISAM services reduces the costs, risk, and non-recurring engineering necessary to deliver ISAM operations. At the same time, in parallel with developing and adopting servicing interfaces on its space systems, the U.S. government should also invest in research and development to advance the maturation of physical docking mechanisms for robotic systems to safely and reliably dock with unprepared and legacy orbital debris objects.

B. Long-Term R&D Priorities

1. Characterization and Detumbling of Tumbling objects

Additional research is needed to advance the tools, sensors, models, and approaches for in-space characterization of complex object tumble rates and, once they are characterized, methods and tools to reduce their tumble rates so that they can be safely serviced. The advancement of safe, routine, and predictable 'universal docking' will mark an inflection point in the long-term advancement of space operations enabled by ISAM, and in the development of the space economy. The capacity to reliably reduce debris object tumble rates to acceptable levels for safe docking and removal is paramount to the realization of routine, widespread, and cost-effective active debris removal activities, without which the long-term growth of the orbital debris population will compromise the utility of strategically advantageous orbital regions.

2. Modularity

As noted in Astroscale's comment into OSTP's Orbital Debris Research and Development Plan,[4] research and development of many of the technologies, methods, and tools necessary to remediate orbital debris and stewardship of the space environment also advance the maturity of other ISAM activities. The

[4] *Call to Action: Astroscale U.S. Vision to Implement Federal Orbital Debris R&D Priorities*, Astroscale U.S. (Jan. 13, 2022), https://astroscale-us.com/national-orbital-debris-priorities/

U.S. government should invest in research and development of modular systems- and component-level design approaches for both spacecraft and servicers, with a priority of advancing modular power and fuel systems designs. Designing both space systems and missions to be not only serviceable but upgradeable and reconfigurable, and to enable ISAM servicer spacecraft to adapt to a range of clients and servicing demands once already on orbit, is the next iteration of today's ISAM service offerings such as life extension.

Future modular, reconfigurable space system architectures will enjoy a higher longevity and return on investment through adaptive mission options, extended operational lifetimes, access to servicers with advanced swappable tool sets, and eventual recycling or repurposing of components and materials for in-space manufacturing and resource utilization applications.

III. What infrastructure, ground, space-based, or digital, or other non-monetary resources will be critical to enabling the advancement of ISAM capabilities and the commercial ISAM industry?

The advancement of ISAM capabilities and the commercial ISAM industry requires clarity of mission authorization and supervision, assured access to spectrum, and iterative approaches to regulation.

A. Clarity of Mission Authorization and Continuous Supervision

Astroscale U.S. and other U.S. industry developing novel ISAM technologies and services will benefit from a clearly established mission authorization framework. Such a framework would systematically regulate risk and safeguard the public interest while alleviating the threat of oversight vagueness that currently hamstrings global competitiveness of the burgeoning U.S. ISAM industry.

In the coming five to ten years, many commercial ISAM missions will partially or fully fall outside of clearly established agency jurisdictions for authorization.[5] As a consequence, authorization and licensing of these novel commercial space activities is at risk of being achieved in a piecemeal manner via disparate mission elements. Additionally, lack of established precedent can introduce subjective agency-by-agency discretion, as opposed to well-justified and coordinated standards and requirements. Divorced and subjective oversight creates uncertainty for investors and insurers of novel services and impedes the development of the commercial ISAM market.[6]

The U.S. government must coordinate among the interagency to clarify authority for oversight and licensing of commercial ISAM capabilities. Mission authorization must avoid imposition of undue, duplicative disclosure burdens and moderate timelines for license application review. Further, any identified mission authorizer for novel space activities must be adequately resourced to serve as shepherds

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[5] *See* Comments of the Consortium for the Execution of Rendezvous and Servicing Operations, RIN 0648-BA15, *Licensing of Private Remote Sensing Space Systems – Advanced Notice of Proposed Rulemaking* (July 15, 2019), https://www.satelliteconfers.org/wp-content/uploads/2019/07/CONFERS_Comment_NOAA_NPRM_07152019.pdf; Comments of Space Logistics, LLC., Docket No. NOAA-NESDIS-2018-0058, *Licensing Private Remote Sensing Space Stations* fn. 37 (July 15, 2019), https://downloads.regulations.gov/NOAA-NESDIS-2018-0058-0030/attachment_1.pdf.

[6] Josef F. Koller, Rebecca Reesman & Tyler Way, *Emerging Issues In New Space Services: Technology, Law, and Regulatory* Oversight, Aerospace Corp. 4 (Sept. 2020), https://aerospace.org/sites/default/files/2020-09/Koller_EmergingIssues_20200914.pdf ("The current uncertainty created by an ad how approval process for many of these [ISAM] activities makes it difficult for commercial companies to develop new business opportunities and get them funded."); Rebecca Reesman, *Assurance Through Insurance and On-Orbit Servicing*, Aerospace Corp. (Feb. 2018), https://aerospace.org/sites/default/files/2018-05/OnOrbitServicing.pdf (noting that "[w]ith fed established examples to assess, it is difficult to develop a complete framework for optimizing risk management and insurance for on-orbit servicing").

of the process for future novel commercial activities.[7] Together, clarification of mission oversight, coordinated government reviews, and adequate agency funding will advance the United States as an attractive regulatory environment for innovative ISAM capabilities.

B. Assured Access to Spectrum

Radiofrequency (RF) spectrum usage for ISAM missions is unique as compared to traditional satellite service providers (such as broadcasting and fixed-satellite service) and other mission types. A government ISAM strategy must architect a spectrum access plan that is responsive to rare-occurrence, high-fidelity spectrum needs, as well as recurring, low-data use.

First, ISAM missions will include time-limited – but critical – stages of communications for RPOD operations, analogous to go/no-go stages during launch vehicle launch and re-entry operations. At mission "waypoints," assured access to spectrum and communication with ISAM servicer spacecraft free from interference is critical to mission safety.[8] Currently, there remains uncertainty around the U.S. regulatory approach to ensuring access to spectrum for ISAM operations and other novel and emerging in-space activities.[9] The most regulatory appropriate and infrastructure viable bands for these critical stages of RPOD use cases are currently restricted for primary federal operator use, excluding or overly limiting commercial access.[10]

Many ISAM missions also require spectrum access to communicate routine spacecraft health checks with operations centers. This spectrum usage will be recurring but not mission-critical, making these connections a candidate for coordinated or non-primary access alongside other operators.

The OSTP and the wider ISAM Interagency Working Group should collaborate with the Federal Communications Commission (FCC) and the National Telecommunications and Information Administration (NTIA) to incorporate RPOD and ISAM spectrum needs into the national spectrum plan.

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[7] In 2016, the Office of Science and Technology Policy (OSTP) noted that the Obama administration was "actively pursuing mechanisms...to enable the Government to authorize innovative new space activities by U.S. companies," and recommended a "narrowly tailored" process. *See* EXECUTIVE OFFICE OF THE PRESIDENT OSTP, LETTER TO CHAIRMAN THUNE AND CHAIRMAN SMITH, (2016). https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/csla_report_4-4-16_final.pdf

[8] *CONFERS On-Orbit Servicing (OOS) Mission Phases)*, Consortium Execution Rendezvous & Serv. Ops. At 7.3 (Oct. 1, 2019), https://www.satelliteconfers.org/wp-content/uploads/2019/10/OOS_Mission_Phases.pdf.

[9] Comments of Astroscale U.S., Inc., Axiom Space Inc., Atomos Space, Sierra Space Corp., and SCOUT Inc., FCC ET Docket No. 13-115 at 5 (Aug. 11, 2021), https://www.fcc.gov/ecfs/file/download/DOC-5ecdbb9ad6000000-A.pdf?file_name=Joint%20Comment_ASUS_Axiom_Scout_Sierra_Atomos%20RM%2013.115.pdf.

[10] ISAM technologies have a limited spectrum usage, usually only requiring bandwidth for telemetry tracking and command (TT&C) links, or imagery download. Internationally, the ITU-defined Space Operation Service is definitionally the most correct radiocommunication service for ISAM missions. *See* ITU, Radio Regs. Art. 1.23 (2022) (defining "space operations service" as "a radiocommunication service concerned exclusively with the operation of spacecraft, in particular space tracking, space telemetry and space telecommand. These functions will normally be provided within the service in which the space station is operating"). Internationally, portions of the 2 GHz are allocated on a primary basis to the Space Operations Service and would provide an internationally aligned and interference-protected spectrum in which to perform critical operations of ISAM. However, the U.S. has reserved these band portions for Federal use. *See* 47 C.F.R. 2.106 (2021) (at 2025-2110 MHZ and 2200-2290 MHz). These bands would serve to accommodate RPO activities, as they already support government RPO activities in relation to the ISS. *See* Comments of Astroscale U.S., Inc., Axiom Space Inc., Atomos Space, Sierra Space Corp., and SCOUT Inc., FCC ET Docket No. 13-115 at 4, 6-7 (Aug. 11, 2021), https://www.fcc.gov/ecfs/file/download/DOC-5ecdbb9ad6000000-A.pdf?file_name=Joint%20Comment_ASUS_Axiom_Scout_Sierra_Atomos%20RM%2013.115.pdf

U.S. leadership in enabling the advancement of ISAM capabilities and successful maturation of the commercial ISAM industry will rest in large part on its approach to spectrum use management for ISAM services.

C. Iterative Approaches to Regulation

The U.S. aerospace industry's economic competitiveness, technological innovation, and attractiveness to investors is strongly tied to clear, streamlined, and minimally burdensome licensing regimes that maximize mission safety and the long-term sustainability of Earth orbits. The ongoing development of ISAM capabilities necessitates a regular revisitation and update cadence for regulations applicable to ISAM technologies and commercial industry providers of ISAM services. For example:

1. Export Control

ISAM operations can include export of commodities or defense services controlled under both the International Traffic in Arms Regulations (ITAR) and the Export Administration Regulations (EAR).[11] The U.S. Department of State should seek public comment to revise and update Category XV of the U.S. Munitions List, last updated over 5 years ago,[12] to account for recent industry developments and more precisely describe and justify the articles warranting control in the category.[13]

2. Non-Earth Imaging Licensing

Similarly, many ISAM technologies and operations utilize onboard cameras and other in-space sensing equipment to ensure mission assurance and safety of RPOD operations. The National Oceanic and Atmospheric Association (NOAA), in coordination with the Department of Defense (DOD), should revisit its policy that commercial use of non-Earth imaging (NEI) in-space cameras and sensors whose primary application is for safe execution of RPOD operations is not exempted "mission assurance,"[14] and consider redesignation and clarification of licensing processes for such uses as mission assurance.[15]

3. Federal Debris Mitigation Requirements

Last, the U.S. government should task the National Aeronautics and Space Administration (NASA) to lead the re-evaluation and update of debris mitigation guidelines influencing civil and defense procurement requirements, chiefly the U.S. Government Orbital Debris Mitigation Standard Practices (ODMSP), at least once every three years. In December 2019, after months of interagency deliberation, NASA released an

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[11] *See* 22 C.F.R. 121.1 (2022) (at Category XV); 15 C.F.R. Part 774, Supplement No. 1 (2022) (at Commerce Control List category 9 – Aerospace and Propulsion).

[12] *See International Traffic in Arms Regulations: Revision of U.S. Munitions List Category XV*, 82 Fed. Red. 2889 (Jan. 15, 2017).

[13] The Department of State did issue an Advanced Notice of Proposed Rulemaking that inquired about Category XV, but no subsequent action has been forthcoming. *See Review of the United State Munitions List Categories IV and XV*, Advanced Notice of Proposed Rulemaking, Docket No. DOS-2018-0048 (rel. Mar. 8, 2019).

[14] Comm. Remote Sensing Reg. Aff., Guidance Circular 960.2-1(Apr. 1, 2022), https://www.nesdis.noaa.gov/s3/2022-04/Guidance_%20Mission%20Assurance%20%20040122.pdf ("Likewise, an instrument that images another operator's spacecraft(s) does not meet this [mission assurance or other technical purposes] exemption, because the imaging is done as a service for another operator rather than to assure the safety of the mission.").

[15] Comments of the Consortium for the Execution of Rendezvous and Servicing Operations, RIN 0648-BA15, *Licensing of Private Remote Sensing Space Systems – Advanced Notice of Proposed Rulemaking* (July 15, 2019), https://www.satelliteconfers.org/wp-content/uploads/2019/07/CONFERS_Comment_NOAA_NPRM_07152019.pdf ; Comments of Space Logistics, LLC., Docket No. NOAA-NESDIS-2018-0058, *Licensing Private Remote Sensing Space Stations* (July 15, 2019), https://downloads.regulations.gov/NOAA-NESDIS-2018-0058-0030/attachment_1.pdf.

updated version of the ODMSP, its first update since 2001. This update provided new standards for U.S. government spacecraft design and missions, but left gaps to be addressed and fell short of industry-developed standards to limit the generation of debris, such as the shortening of targeted post-mission disposal timeframes from 25 to 5 years after end-of-mission. The disparities between industry and government best practices which undercuts the creation of a consistent and robust U.S. government demand signal for commercial ISAM industry capabilities.

Further, U.S. government compliance with the ODMSP is not publicly available information, curtailing the Practices' efficacy as a tool to foster the responsible use of space. The Interagency Working Group should consider enacting a formal measure in the ODMSP requiring that civil USG space system operators requesting waivers or exemptions to policy from ODMSP requirements to, as a condition of a waiver, first evaluate and utilize U.S. commercial ISAM service offerings to achieve compliance, such as through life extension, refueling, or third-party post-mission disposal ("direct retrieval").

IV. What factors (e.g., demand for services, lack of regulation, government funding, USG space priorities and space architecture decisions, significant debris event) may accelerate or decelerate progress in the development and advancement of the ISAM industry?

The U.S. government can accelerate progress in the development and advancement of the ISAM industry by evaluating current market offerings and standards, clarifying U.S. government problem sets, capability gaps, and use cases for ISAM, considering liability and insurance requirements for commercial ISAM activities, and enhancing international coordination and cooperation, namely through the pursuit of joint ADR missions, starting with a coalition of likeminded nations. Decelerates of progress include insufficiently coordinated or resourced 'one-off' investments in ISAM, overly restrictive regulatory constraints on commercial ISAM activities or technologies, and a failure to advance debris remediation.

A. Accelerants of Progress

To fully enact its strategic goals to advance R&D, enhance stakeholder coordination, and send a strong demand signal for commercial ISAM capabilities and services, the following U.S. government actions and factors would serve as accelerants of progress:

1. Evaluation of current market offerings and standards

The national alliance outlined in the Strategy, in coordination with NASA's OSAM Initiative, should conduct a state-of-the-field audit of the range and current state of emerging commercial and academic research and technology development across ISAM applications and services. This audit should build on previous and current studies to incorporate industry-led best practices and standards for ISAM mission operations, and the authors should regularly update it to account for the rapid pace of innovation. A shared U.S. government understanding of the current state of efforts already underway in academic and industry organizations is vital to ensuring future federal R&D investment plans are well-informed.

2. Clarity of U.S. government problem sets, capability gaps, and use cases for ISAM

Commercial ISAM industry stakeholders are presented with varying, and occasionally conflicting, statements regarding U.S. government ISAM capability gaps and procurement needs. The Interagency Working Group should lead the execution of a cross-agency strategic needs evaluation to clearly define the problem sets, challenges, capability gaps, and use cases for which the U.S. government's civil and defense space stakeholders seek to develop and procure commercial solutions. The space enterprise needs a coordinated, robust, and clear public roadmap explaining how to integrate current and future commercial ISAM capabilities to address upcoming program needs in the short- to mid-term. This also includes clearly

defining where procurement authorization and budgetary responsibilities lie for such capabilities, particularly programs seeking to procure ISAM services, and not servicing systems themselves. Enhanced clarity will help to guide private investments and improve the ability of industry stakeholders to address federal needs.

3. Consideration of liability and insurance requirements

For any emerging industry, the regulatory approach to risk measurement, management, and enforcement is a vital factor shaping the pace and sustainability of its growth. In the near future, commercial ISAM missions will involve customers and service providers from differing nations. Because little legal precedent or formal agreement between nations exists for the liability, indemnification considerations, and insurance requirements for such missions outside of the U.N. treaty system, domestic clarity of the U.S. approaches to these issues will bolster the U.S. ISAM industry's global competitiveness. Similarly, in coordination with industry, the Office and the Working Group should, in coordination with Congress, convene interagency dialogue to consider the application of capped or tiered liability indemnification structures for ISAM operations. The dialogue should also examine the utility of insurance requirements or other incentives for insuring ISAM missions, to enable the healthy growth of the market. Such interagency dialogue should also consider where jurisdictional authority should rest to enact such measures.

4. International Coordination and Cooperation

The United States is a leading contributor to international venues for coordination of orbital debris mitigation and long-term sustainability of space, including through the transparent use of ISAM capabilities. The United States has also demonstrated global leadership in implementation and championship of guidelines and norms of responsible space behaviors reached within these venues. Continued U.S. engagement in these efforts should include work to construct appropriate routes and methods for provision of prior notification to international satellite operators in advance of ISAM missions, in keeping with principles of due regard. Because some ISAM capabilities may be considered to apply dual-use technologies, common avenues and means for transparent notification will strengthen confidence in the safety of ISAM services and reduce the risk of misinterpretations surrounding increased RPOD operations.

This coordination should be paired with the commencement of joint ISAM demonstration missions and programs with other spacefaring nations, beginning with active debris removal (ADR). ADR of high-mass, high-risk debris objects is a servicing operation involving RPOD and the responsible, peaceful use of ISAM capabilities. A U.S.-led partnership to enact a joint ADR demonstration effort would mature technology readiness levels (TRLs) of the capabilities and methods to remove large, high-risk debris objects that pose a danger to spaceflight operations. Starting with a coalition of likeminded allied nations, with the explicit goal of expanding such partnerships to include the broader international community, this effort would also serve as a 'policy demonstration' to resolve lingering legal uncertainties around international ADR missions, such as liability apportionment, jurisdiction and control, and registration of debris objects involved in ADR servicing missions. A joint ADR effort would be a compelling lever to strengthen geopolitical momentum for international engagement and buy-in around norms of responsible space behavior. By setting a high bar and legal precedent for the transparent, responsible, and secure execution of ADR missions, a U.S.-led coalition of likeminded nations would advance ISAM capabilities and strategic stability in the space domain.

B. Decelerates of Progress

In the long-term, many of the factors that stand to decelerate the progression of ISAM capabilities also endanger the advancement of other space capabilities. Insufficiently resourced, under-coordinated, and

"one-off" demonstration or procurement models will fail to sustain a robust demand signal for ISAM services and technologies or enable the emergence of the ISAM market. Similarly, isolated ISAM demonstrations or programs that fail to meaningfully address and resolve policy, regulatory, and licensing hurdles and uncertainties will impart costly and burdensome delays on emerging commercial providers.

In the same way, regulation that overly constrains technologies that underpin ISAM services will slow development, standardization, and adoption of ISAM capabilities and docking interfaces. To hasten the onset of a 'servicing culture,' of space operations, regulatory standards for ISAM services must center around desired behaviors and be performance-based, rather than enacting restrictions on specific technologies, components, or capabilities. The rapid pace of technological innovation often renders constraints of specific technologies obsolete and can reduce U.S. ISAM providers' competitiveness in the global market.

Finally, the United States and other leading spacefaring nations must take measurable and significant steps to develop and procure services to remediate high-mass, high-risk debris objects in Earth orbit. A failure to do so will contribute to uncontrolled growth in the rate of conjunctions, break-up events, collisions, and other fragmentations in Earth orbit. This will compound the risks to spaceflight safety and jeopardize the utility of the orbital domain, for ISAM applications and for the benefit of humanity.

V. What are the most effective kinds of partnerships, between the U.S. Government, industry, and academia, that would advance ISAM industry maturity and ISAM capabilities? What partnership opportunities exist, both nationally and internationally, outside of the Federal Government?

The U.S. Government can harness effective partnership models to advance ISAM capabilities, including government-industry information and personnel exchanges, expanding access to federal testing facilities, and Advanced Market Commitment procurement structures. The Office and the Working Group should also engage closely with ISAM industry consortia and standards organizations such as CONFERS and partner with academia and research organizations to study the economic impact of ISAM capabilities on the space economy.

A. Effective U.S. Government-Industry Procurement and Exchange Relationships

As mentioned in Section IV, U.S. government should coordinate its partnerships and contracting structures to procure ISAM capabilities and services among the interagency. An increased number and rapid cadence of in-space demonstration opportunities is instrumental to advancing the TRLs of enabling technologies underpinning ISAM capabilities. For example, hosted payloads, flight and launch opportunities, and demonstrations that apply COTS, Commercial Crew, and tipping point procurement models are advantageous, as long as the problem statements and desired use cases for commercial technologies are clearly defined.

However, while all effective partnerships involve mutual investment and mutual risk, they need not necessarily involve only the exchange of funds. Stakeholders in the burgeoning commercial ISAM industry would benefit from expanded access to federal expertise, mentorship, lessons learned, and facilities throughout the research and development process. For example, in early stages of testing, there are rapid iterations upon both digital simulations and initial prototypes. Lowering the barriers of access to federal equipment and testing and development labs would significantly accelerate commercial R&D in RPOD simulation, robotics, and interfaces, particularly by small and medium enterprises (SME).

The ISAM industry must move beyond the paradigm of repeated transfer of government-developed technologies for commercial use. The U.S. government should consider applying an Advanced Market Commitment model of procurement for ISAM services. NASA applied this model in its Commercial Orbital Transportation Services (COTS) and Commercial Crew programs. The goals of the COTS program were to reduce U.S. dependence on Shuttle, Soyuz, and Progress for human-rated transport to the ISS and to stimulate competition among U.S. launch service providers.[16] By opening competition and engaging in limited, fixed-price and milestone-driven investments in the highest-scoring proposals, NASA succeeded in establishing a clear demand signal, sparking competition that resulted in a more robust U.S. commercial launch industry. In addition to significant cost savings, other positive knock-on effects of this partnership model included lowered launch prices per kilogram to orbit, the advancement of reusability in launch systems, new customer bases for launch services, and heightened participation in the space economy. The U.S. government should apply this model to its procurement of commercial U.S. ISAM services.

B. Existing Effective Partnerships: Industry Standards Organizations and Consortia

Industry is at forefront of technological advancements and mission design approaches for emerging ISAM capabilities. These stakeholders have formed standards organizations and consortia to identify and cultivate consensus around best practices for safe operations. For example, the Consortium for the Execution of Rendezvous and Servicing Operations (CONFERS) has developed a record of research publications, public comments on government regulatory proceedings, communal guiding principles for commercial services, recommended design practices, and presentations to international audiences.[17]

As noted in the Strategy, ISAM interagency stakeholders must prioritize ongoing dialogue with industry players. In addition to including ISAM industry representatives in relevant federal advisory committees, U.S. government stakeholders should continue to convene industry days centering around ISAM capabilities and participate in conferences and industry group meetings. ISAM industry representatives from both small and medium enterprises (SME) and traditional enterprise organizations should be appointed to the National Space Council's User Advisory Group. As the Office and the Interagency Working Group convenes its own nationwide consortium of stakeholders, it should include and engage with closely with CONFERS and other groups to explore how the interagency can best support their ongoing efforts and glean lessons learned. The nationwide alliance should conduct its meetings publicly, at a regular cadence.

The U.S. government should facilitate greater ISAM industry presence and inputs into multilateral and international fora. For example, the U.S. should incorporate ISAM activities into its delegation's engagements within the United Nations Committee on the Peaceful Uses of Outer Space's Long-Term Sustainability (LTS) 2.0 working groups. These engagements should include discussion of, for example: how nations can independently and jointly harness ISAM capabilities in their implementation of the first set of 21 LTS Guidelines; routes and methods for providing prior notification and transparent execution of ISAM activities; means to encourage standardization and adoption of interfaces for servicing among member states, as a measure to mitigate and manage the orbital debris population; standards and best practices for the responsible application of ISAM capabilities; and joint cooperation on ISAM activities, including ADR. The U.S. government should harmonize these engagements with its contributions and

[16] National Aeronautics and Space Administration, *Commercial Orbital Transportation Services: A New Era in Spaceflight*, (February 2014), at 10-12. https://www.nasa.gov/sites/default/files/files/SP-2014-617.pdf
[17] *See* "Publications," CONFERS (Last accessed 28 June 2022). https://www.satelliteconfers.org/publications/

participation in other international and multilateral venues, such as the Inter-Agency Debris Coordination committee.

C. Needed Partnership: Economic Studies, Tools, and Analysis

Robust economies of scale are dependent on shared understanding of risk, including how it is measured, how much is present, and how much can be tolerated in the financial and physical growth of operations. The U.S. government should partner with academia and research organizations to produce longitudinal studies on the impact of emerging ISAM capabilities on the space economy. Partnership models could include personnel and information exchange programs, short-term and project-specific residencies, fellowships, and grant opportunities.

Research topics could include impacts of ISAM capabilities on the growth of the U.S. space workforce, industrial base, and supply chain, the investigation of financial incentives for timely post-mission disposal, the value of preserving accessible and safe orbital regimes, and other novel space economic concepts, such as a space commodities exchange. These studies would aid in the development of economic, policy, and business tools to advance the sustained growth of ISAM services in the space economy.

VI. What are the highest priority actions that the USG can take over the next five years to implement the goals outlined in the ISAM strategy?

In the next five years, the U.S. Government should prioritize coordinated and sustained investments in research and development, enhanced regulatory clarity for commercial ISAM services, adoption of servicing interfaces, and incorporation of ISAM capabilities into federal space architecture planning and cost-benefit analyses.

A. Coordinated, Sustained R&D Investment

The Office and the Interagency Working Group should lead execution of a whole-of-government systematic evaluation of its strategic needs and audit of commercial ISAM capabilities. Those findings should inform a public roadmap detailing its vision for procurement current and future commercial ISAM capabilities to address upcoming program needs in the short- to mid-term, as well as future architecture planning. The U.S. government should prioritize research and development in autonomy, sensors, and interfaces in the next five years. A flagship ADR program and sustained procurement of ISAM services to advance large, high-risk debris object remediation would facilitate the advancement of many enabling ISAM technologies under its umbrella in parallel. ADR efforts should be conducted jointly with international allies and partners.

B. Enhanced Regulatory Clarity

The U.S. government must coordinate among the interagency to clarify authority for oversight and licensing of commercial ISAM capabilities. A government ISAM strategy must architect a spectrum access plan that is responsive to rare-occurrence, high-fidelity spectrum needs, as well as recurring, low-data use. The ongoing development of ISAM capabilities also necessitates a regular revisitation and update cadence for regulations applicable to ISAM technologies and commercial industry providers of ISAM services, including for export control, non-Earth imaging licensing, and federal debris mitigation requirements.

C. Adoption of Servicing Interfaces

The U.S. government should work to advance a servicing culture across the entire space enterprise by supporting the standardization and adoption of interfaces for servicing as widely as practical across its space systems. For the benefits of ISAM services to scale, governments must include servicing interfaces its

procurement requirements. This will future-proof its systems for future innovations in ISAM service offerings, lower the costs of ISAM services, and galvanize a much-needed shift towards modular space systems and component design.

D. Incorporation of ISAM Capabilities in Architecture Planning and Cost-Benefit Analyses

The U.S. government should incorporate its audits of commercial U.S. ISAM capabilities when assessing its needs and capability gaps and envisioning future defense and civil space architectures. Likewise, in shaping funding plans for future space platforms or systems, cost-benefit analyses should include alternative or novel mission approaches solely enabled by ISAM services such as relocation, life extension, and refueling. In doing so, the U.S. government should maximize existing U.S. taxpayer investments while ensuring the U.S. government refrains from competing with U.S. commercial space market offerings, unless required by national security or public safety.