Before the

FEDERAL COMMUNICATIONS COMMISSION

Washington, D.C. 20554

In the Matter of	)	
	)	
Space Innovation;	)	IB Docket No. 22-271
	)	
Facilitating Capabilities for In-space Servicing,	)	
Assembly, and Manufacturing	)	IB Docket No. 22-272
	)	

COMMENTS OF ASTROSCALE U.S. INC.

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Astroscale U.S. ("Astroscale") hereby submits Comments to the Federal Communications Commission's ("FCC" or "Commission") Notice of Inquiry ("NOI") in the above-referenced proceeding.[1] Astroscale thanks the Commission for the opportunity to expand the record on important issues related to in-space servicing, assembly, and manufacturing ("ISAM") technology.

I. Introduction

The U.S. has reached a precipice yet unencountered in human history: we are ready to build space infrastructure. This infrastructure goes beyond the communications and Earth observation satellites deployed since the 1960s. This infrastructure will host commercial space stations, servicing satellites, fabrication and assembly centers, and will create operational predictability as humans reach for the Moon and Mars. The coordinated actions taken now – beginning with this docket – will have resounding impacts on how servicing, assembly, and manufacturing are conducted off-planet for decades to come.

The umbrella of in-space servicing, assembly, and manufacturing encompasses many discrete mission types.

> "ISAM is a suite of capabilities, which are used on-orbit, on the surface of celestial bodies, and in transit between these regimes. ISAM capabilities enable specific activities in the areas of **servicing**—the in-space inspection, life extension, repair, or alteration of a spacecraft after its initial launch, which includes but is not limited to: visually acquire, rendezvous and/or proximity operations, docking, berthing, relocation, refueling, upgrading, repositioning, undocking, unberthing, release and departure, reuse, orbit transport and transfer, and timely debris collection and removal; **assembly**—the construction of space systems in space using pre-manufactured components; and **manufacturing**—the transformation of raw or recycled materials into components, products, or infrastructure in space. These ISAM capabilities may use technologies that include inter alia, robotics; sensors and software for trusted autonomy; re-entry/deorbit systems; advanced in-space computing; verification and validation; standard interfaces; propulsion systems; systems engineering tools and techniques that support spacecraft serviceability; and low-cost reusable in-space mobility, logistics, and transportation systems, as appropriate."[2]

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[1] *Space Innovation & Facilitating Capabilities for In-space Servicing, Assembly, and Manufacturing*, Notice of Inquiry, IB Docket Nos. 22-271 & 22-272, 87 Fed. Reg. 56365 (Sept. 14, 2022) [*hereinafter* ISAM NOI].

[2] NAT'L SCI. & TECH. COUNCIL, EXEC. OFF. OF THE PRESIDENT, IN-SPACE SERVICING, ASSEMBLY, AND MANUFACTURING NATIONAL STRATEGY 6 (2022), https://www.whitehouse.gov/wp-content/uploads/2022/04/04-2022-ISAM-National-Strategy-Final.pdf (emphasis added) [*hereinafter* ISAM National Strategy]. Additionally, NASA has broken ISAM down into eleven capability areas: (1) robotic manipulation; (2) rendezvous and proximity operations, capture, docking, and mating; (3) relocation; (4) planned repair, upgrade, maintenance, and installation; (5) unplanned or legacy repair and maintenance; (6) refueling and fluid transfer; (7) structural manufacturing and assembly; (8) recycling, reuse, and repurposing; (9) parts and goods manufacturing; (10) surface construction; and, (11) inspection and metrology. *See* DR. DALE ARNEY & DR. RICHARD SUTHERLAND, NASA, IN-SPACE SERVICING, ASSEMBLY, AND MANUFACTURING (ISAM) STATE OF PLAY (2022 eds.), https://nexis.gsfc.nasa.gov/isam/docs/isam_state_of_play_final_2022_v2_S_2022_10_17.pdf.

This list of what ISAM encompasses makes clear, in exquisite comprehensiveness, that ISAM is what underlies the vision of our space future.

Happily, the U.S. does not foray into creating ISAM infrastructure unprepared. Several commercial missions, or demonstrations of commercial technology, have previously taken place and been authorized by the Commission.[3] Additionally, U.S. agencies have significant experience in demonstration and international coordination of ISAM activities, from the historic rendezvous and docking between the Apollo and Soyuz spacecraft, to five discrete instances of in-space manual repairs and upgrades to Hubble. "The United States will build on this foundation to accelerate a new, diverse, and market-focused ecosystem of autonomous persistent platforms and assets, to improve the way we use space for in-space and terrestrial operations."[4]

The Commission has a valuable role to play in the U.S.' space future. Clarity in regulations will help advance research and development in ISAM, prioritize the expansion of both ground and space-based infrastructure, and support a sustainable space ecosystem.[5] Section II of this Comment will provide information on the economic landscape of ISAM, including sources of demand, supply, and project growth in the five and ten-year terms. Section III will relay the technical specifications of ISAM missions, their spectrum use, and radiocommunication services of potential definitional fit, and methods of coordination with existing services. Section IV will discuss Part 5 and Part 25, constructing orbital debris mitigation showings for ISAM missions and who should carry authorization burdens in servicing scenarios. Overall, Sections III and IV will conclude that, most fundamentally, identifying spectrum allocations and licensing for ISAM mission will empower the industry and uphold whole-of-government goals.[6] Section V will discuss the current state-of-the-art in remediation and removal before demonstrating how investment in ISAM supports compliance with orbital debris mitigation requirements. Section VI will briefly discuss intragovernmental and intergovernmental relationships before Section VII offers a conclusion.

II. The ISAM Market: a New Era of Commercial Space.

[3] ISAM NOI, *supra* note 1, at ¶ 5.
[4] ISAM National Strategy, *supra* note 2, at 5.
[5] ISAM NOI, *supra* note 1, at ¶ 9 (summarizing the ISAM National Strategy's six goals to advance ISAM capability development).
[6] *See* Space Policy Directive 3: National Space Traffic Management Policy, 83 Fed. Reg. 28969, 28971 at § 4(g) (June 21, 2018) (under "goals" for U.S. executive departments and agencies, listing, "(g) *Preventing intentional radio frequency interference*….The United States should continue to improve policies, processes, and technologies for spectrum use (including allocations and licensing) to address these challenges and ensure appropriate spectrum use for current and future operations.").

Commercial space operations are plagued by the proverb "out of sight, out of mind." It is easy to forget that space assets allow U.S. consumers to drive to and from work, plan their harvests or evacuate from the path of natural disasters, and reap the benefits of medical innovations.[7] It takes uncommon events, like the conflict in Ukraine, to viscerally remind people how much space assets impact lives.[8]

ISAM operations will create significant benefits for the American people without much of the public being aware of what has occurred. First, ISAM technologies developed – especially in the domains of robotics and sensor systems – will have common benefits in medicine, autonomous operations, and more.[9] Second, ISAM missions will sustainably extend the life of critical assets, like GPS or weather-monitoring satellites, without consumers having to overcome service disruptions.[10] Third and finally is the most perceivable benefit – ISAM companies offer highly-skilled career positions. Astroscale U.S., incorporated in 2019, has grown in just three years to employ over fifty persons in Colorado and Washington D.C. Promoting the ISAM industry's commercial development is in the public interest.

The Commission asks several questions about the current state of ISAM technology and its economic impact on space-based services.[11] The following subsections will address these questions. First, information on the *current* ISAM market will be provided, including who and where is generating consumer demand and the current suppliers to meet such demand. Second, Astroscale will comment on the future technologies and economic impact of space-based services, projecting what the industry will look like in five and ten years.

A. Current Supply and Demand of ISAM Services.

The Commission asks what entities supply and demand ISAM services.[12] This section will explore the fact that ISAM market growth is initially driven by the "servicing" element. As assembly and manufacturing portions of ISAM are still nascent technologies as compared to servicing, the majority of the following analysis will be for activities under the "servicing" portion of ISAM.

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[7] *See, e.g.*, Carah Barbarick, *A Look at How Technologies Devised for Space Have Revolutionized Healthcare*, SPACE FOUNDATION (2022), https://www.spacefoundation.org/2020/03/26/a-look-at-how-technologies-devised-for-space-have-revolutionized-healthcare/ (noting medical innovations developed from, or created using, space systems).

[8] *See* Jacqueline Feldscher, *The Ukraine War Is Giving Commercial Space an "Internet Moment,"* DEFENSE ONE (Apr. 7, 2022), https://www.defenseone.com/technology/2022/04/ukraine-war-giving-commercial-space-internet-moment/364101/.

[9] *See, e.g.*, Elizabeth Howell, *How a Robot arm in Space Inspired Tech for Surgery on Earth*, Space.com (Mar. 7, 2018), https://www.space.com/39899-space-robotic-arm-inspires-surgery-tool.html (noting that the Canadarm technology on the International Space Station is a common model for medical spin-offs).

[10] *See* Chris Gebhardt, *Mission Extension Vehicles Succeed as Northrop Grumman Works on Future Servicing/Debris Clean-up Craft*, SPACEFLIGHT.COM (May 7, 2021), https://www.nasaspaceflight.com/2021/05/mev-success-ng-future-servicing/ (noting MEV-2 docked to an operational and transmitting Intelsat 10-02 without any service interruptions).

[11] ISAM NOI, *supra* note 1, at ¶ 40.

[12] *Id.* ("What firms currently supply ISAM services? What entities demand ISAM services?").

i. Current ISAM Demand is Generated Across NGSO and GSO, and is Geographically Diverse.

Currently, the useful life of a spacecraft is hindered by the inability of the market to provide servicing or repairs after launch; this constrains the mass, size, and mission design of spacecraft and reduces the ability to provide continuous updates to a given system. Additionally, servicing capabilities – such as end-of-life services ("EOL") and active debris removal ("ADR") – are essential and vital countermeasures to the collision risk and debris challenges posed by the upsurge in orbital congestion.[13] Today's predominant demand driver is the need to prolong the operational life of space assets and remove orbital risks.[14]

Demand for ISAM services can be delineated between government and commercial operators.[15] Globally, the commercial sector drives the need for ISAM services, representing most of market demand. Commercial demand flows from both non-geostationary ("NGSO") and geostationary ("GSO") satellite constellation providers (e.g. SpaceX, SES), operators of "exquisite" satellites (e.g. Maxar, GlobeStar),[16] commercial exploration operators (e.g. Axiom, SpaceX),[17] as well as non-profit and academic institutions.[18] The remaining 32% of aggregate demand is from government operators internationally, including domestic national security entities such as the U.S. Space Force and global civil space operations such as NASA or the European Space Agency.[19]

Additionally, demand can be analyzed by orbital region. Needs for ISAM services in the coming decade are overwhelmingly concentrated in NGSO, primarily driven by the need to remove satellites from

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[13] NAT'L SCI. & TECH. COUNCIL, EXEC. OFF. OF THE PRESIDENT, NATIONAL ORBITAL DEBRIS IMPLEMENTATION PLAN 6 (2022), https://www.whitehouse.gov/wp-content/uploads/2022/07/07-2022-NATIONAL-ORBITAL-DEBRIS-IMPLEMENTATION-PLAN.pdf [[*hereinafter* Orbital Debris Implementation Plan].
[14] *See* ARNEY & SUTHERLAND, *supra* note 2, at 1.
[15] ISAM NOI, *supra* note 1, at ¶ 40 ("What entities demand ISAM services?").
[16] An "exquisite" satellite is a large, highly-sophisticated satellite, usually based in GSO for imagery or intelligence community missions. *See, e.g.*, Greg Avery, *"Exquisite" Is Out, Smaller Is Big at the National Space Symposium*, DENVER BUS. J. (Apr. 12, 2013), https://www.bizjournals.com/denver/blog/boosters_bits/2013/04/exquisite-is-out-smaller-is-big-at.html.
[17] An "exploration operator" encompasses "operators and manufacturers of on-orbit platforms, crew and/or cargo vehicles, surface infrastructure, and other space systems utilized for space operation." BryceTech, CONFERS Market Research Report and Business Plan 28 (Aug. 26, 2022) (unpublished manuscript) (on file with the Author) [*hereinafter* BryceTech]..
[18] *Id.*
[19] *Id.* Both Astroscale U.K. and Astroscale Japan are currently supporting ISAM contracts for government partners. *See Astroscale Forges Ahead with U.K. Active Debris Removal Mission with Support from U.K. Space Agency*, Astroscale (Sept. 26, 2022), https://astroscale.com/astroscale-forges-ahead-with-uk-active-debris-removal-mission-with-support-from-uk-space-agency/; *Astroscale Selected as Contract Partner for Front-Loading Technology Study in Phase II of JAXA's Commercial Removal of Debris Demonstration Project*, ASTROSCALE (Aug. 22, 2022), https://astroscale.com/astroscale-selected-as-contract-partner-for-front-loading-technology-study-in-phase-ii-of-jaxas-commercial-removal-of-debris-demonstration-project/.

orbit at end-of-life.[20] Despite this, roughly 44% of cumulative global revenues are projected to stem from GSO services through 2031, suggesting a strong business case for GSO servicers.[21] While life extension services currently exist for GSO assets, future advancements in ISAM capability will allow these satellites to be refueled as needed while incorporating hardware updates over several decades.

Finally, from a geographic perspective, most demand for ISAM services is concentrated in North America, Europe, and Asia. These regions are projected to be the most significant market segments in the coming decade, given the number of assets currently operating in orbit. The European market is expected to experience the most growth over this timeframe, with the region owning the world's second-largest public space budget and growing demand for satellite-based services.[22]

ii. ISAM Service Providers – Growing Nationally and Internationally.

ISAM service providers are growing in number and capability worldwide, commensurate with the uptick in consumer demand.[23] Internal research identified over 102 companies at varying degrees of maturity planning to offer ISAM services. More ISAM companies are working in the U.S. than in the rest of the world combined, with over 70% having a domestic presence.[24]

The hundred-plus planned providers of ISAM services are all at different development stages.[25] Only six currently possess fully operational servicers: four in the U.S., with the other two being based in Australia and Italy.[26] Another twelve providers have partially demonstrated ISAM systems. These include another seven U.S.-based providers and others based in Brazil, China, France, Japan,[27] and Russia.[28] It is

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[20] *See, e.g.*, *Space Innovation Mitigation of Orbital Debris in the New Space Age*, Second Report & Order, (FCC) FCC-22-74, at ¶ 20 (Sept. 29, 2022).

[21] Astroscale internal research. The value derived from servicing GSO assets has, to date, been higher than that for servicing NGSO assets. Satellites in GSO are of higher value on a dollar-per-kilogram basis and dollar-per-asset basis than NGSO counterparts. Additionally, unique market dynamics are leading GSO commercial operators to want to extend the life of their satellites; namely, the ability to maintain valuable orbital slot positions and provide consistent coverage. *See, e.g.*, MARTHA MEJIA-KAISER, THE GEOSTATIONARY RING: PRACTICE AND LAW 139 (2020) (noting that in a recent audit of GSO filings, the Radiocommunication Bureau of the ITU became aware of 145 registrations that were "not used by the corresponding administrations or were not clarified at all. The Bureau deleted these registrations from the Master Register…"). Studies indicate that more than half of current GSO satellites will have operational interruptions simply due to a fuel shortage despite being otherwise functional. Alec J. Cavaciuti, et al., *Game Changer: In-Space Servicing, Assembly, and Manufacturing for the New Space Economy*, AEROSPACE 10 (2022), https://csps.aerospace.org/sites/default/files/2022-07/Cavaciuti-Davis-Heying_ISAM_20220715.pdf.

[22] *Europe Small Satellite Market – Growth, Trends, COVID-19 Impact, and Forecasts (2022-2027),* MORDORINTELLIGENCE (2022), https://www.mordorintelligence.com/industry-reports/europe-small-satellite-market.

[23] ISAM NOI, *supra* note 1, at ¶ 40 ("What firms currently supply ISAM services?").

[24] BryceTech, *supra* note 17, at 14.

[25] ISAM NOI, *supra* note 1, at ¶ 40 ("What firms currently supply ISAM services?").

[26] BryceTech, *supra* note 17, at 14.

[27] The end-of-life servicing demonstration, operated by Astroscale Ltd. ("Astroscale U.K."), was labeled by the BryceTech study as a Japanese capability; Astroscale U.K. is a wholly-owned subsidiary of Astroscale Holdings, a Japanese corporation.

[28] *Id.*

estimated that as many as forty other ISAM providers worldwide are in the advanced stages of development, with the potential to provide operational service within the next five years.[29]

Astroscale companies are lead suppliers for on-orbit inspection and movement of client spacecraft worldwide.[30] Global services offered include end-of-life removal for prepared NGSO satellites, active debris removal for large debris, life extension in GSO, and inspection for space situational awareness across all orbits.[31] Astroscale U.K.'s 2021 End-of-Life Service by Astroscale demonstration (ELSA-d) successfully demonstrated the use of the following technologies: autonomous guidance, navigation, and control algorithms; closed-loop control with onboard navigation sensors; autonomous thruster rendezvous maneuvering and attitude control; transition from absolute to relative navigation using onboard LPR sensors; magnetic capture mechanism using a docking plate.[32]

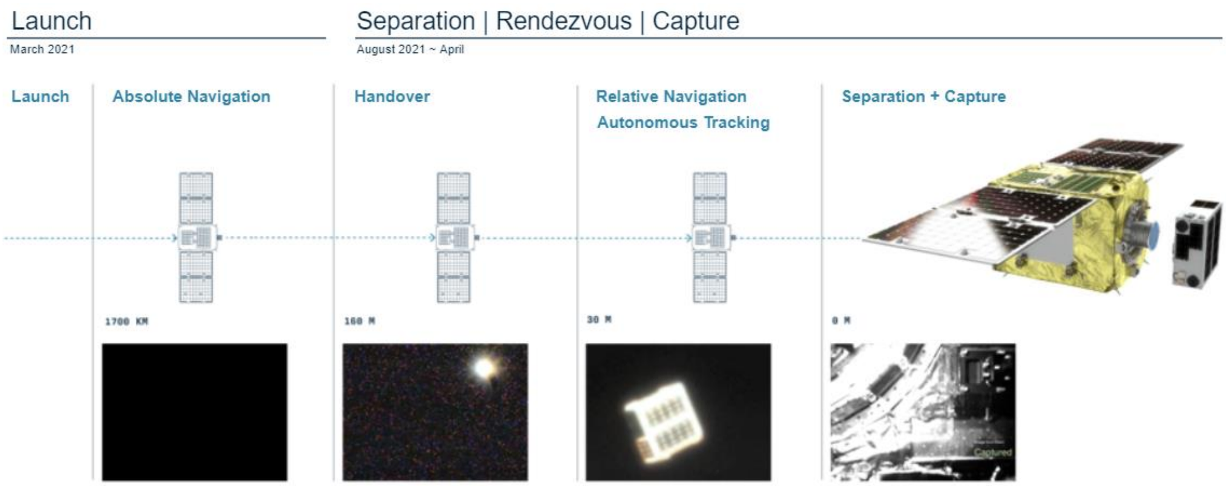

Figure 1: Proven core technologies required for on-orbit servicing by the ELSA-d mission.

Commercial end-of-life services will be supplied by ELSA-M spacecraft; the in-orbit demonstration with a constellation customer is planned for 2024.[33] From Japan, the Active Debris Removal by Astroscale-Japan (ADRAS-J) spacecraft will launch in 2023 to complete the inspection of a derelict upper-stage rocket body.[34] Nationally, Astroscale U.S. is the mission prime for the Life Extension (LEX) program, with payload research and payload development support from Astroscale Israel ("ASIL"). The first servicer spacecraft in the LEX program, LEXI-1, is anticipated to launch in 2025.

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29 *Id.*
30 Headquartered in Japan, Astroscale Holdings has an international presence with subsidiaries in the United Kingdom, the United States, Israel, and Singapore.
31 *See Services*, ASTROSCALE (2022), https://astroscale.com/services/.
32 *Astroscale's ELSA-d Mission Successfully Completes Complex Rendezvous Operation*, ASTROSCALE (May 4, 2022), https://astroscale.com/astroscales-elsa-d-mission-successfully-completes-complex-rendezvous-operation/.
33 *ELSA-M*, ASTROSCALE (2022), https://astroscale.com/elsa-m/.
34 *See Astroscale Selects Rocket Lab to Launch Phase I of JAXA's Debris Removal Demonstration Project*, ASTROSCALE (Sept. 21, 2021), https://astroscale.com/astroscale-selects-rocket-lab-to-launch-phase-i-of-jaxas-debris-removal-demonstration-project/.

Other players offering complementary services in the ISAM value chain include Northrup Grumman Space Logistics, D-Orbit, OrbitFab, and Maxar.[35] Other entities at advanced stages of development in the assembly and manufacturing activities include Maxar, Redwire, and Arkisys, though the time horizon on those capabilities is in the mid-to-long-term.[36]

B. The ISAM Sector Will Grow Significantly Over the Next Five- and Ten-Year Periods.

The Commission asks how ISAM innovations will impact the space-based industry when evaluated through long-term projections.[37] The following subsections will explore these projections on a five- and ten-year timeframe. Within ten years, ISAM missions will influence not only the cleanliness of the orbital environment but also how to-be-launched spacecraft are designed and expected to operate.

i. Five-Year Outlook: Infrastructure, New Technologies, and Standards.

In the next five years, ISAM innovations will underly the creation of infrastructure and contribute to new technologies and standards for the space-based industry.

ISAM innovations in the next five years will support the realization of NASA mission operations such as the Lunar Gateway and subsequent Artemis missions to Mars. Consistent rendezvous, proximity, and docking operations will be a critical part of allowing ongoing transfers, transport operations, and the addition of subsequent modules for these programs.[38] Infrastructure development will further spur future investment in market activities and contributes to the projected rapid increase of global ISAM revenues from $424.3 million in FY22 to $1.67 billion by FY27.[39]

The growth of ISAM operations will also contribute to technological and standards development over the next five years. Technological growth is expected in increased autonomy and sensing techniques, as these technologies enable satellite servicing for inspection and orbit modification.[40] For example, improvements to the sensors for rendezvous, proximity operations, and docking ("RPOD") technologies are also expected in the near term, including research to test the applicability of terrestrial market off-the-shelf sensors for use in RPOD, given that the quality of currently available space-rated sensors ideal for commercial RPOD applications is often either insufficient or prohibitively expensive for bespoke solutions.

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[35] BryceTech, *supra* note 17, at 15.
[36] BryceTech, *supra* note 17, at 16.
[37] ISAM NOI, *supra* note 1, at ¶ 40 ("How does innovation in such technologies and service impact the space-based industry when evaluated through long-term projections (e.g., a five-year projection or a ten-year projection)?").
[38] *Astroscale U.S. + Orbit Fab Sign The First On-Orbit Satellite Fuel Sale Agreement*, SATNEWS (Apr. 13, 2022), https://news.satnews.com/2022/04/13/astroscale-u-s-orbit-fab-sign-the-first-on-orbit-satellite-fuel-sale-agreement/#:~:text=Astroscale%20U.S.%20is%20working%20with%20Orbit%20Fab%20to,to%20develop%20LEXI%E2%80%99s%20rendezvous%20and%20docking%20payload%20technology.
[39] Astroscale internal research.
[40] *See* Alec J. Cavaciuti, et al., *supra* note 21, at 10-11.

Additionally, advancements in machine learning and artificial intelligence methods and tools for RPOD operations and mission planning are expected. As has been proven for their cousins in autonomous collision avoidance operations, these methods can aid tremendously in hastening routine autonomous RPOD with minimal human-in-the-loop involvement. Thus far across the space enterprise, RPOD has been a significant component of space missions but has largely been constrained to heavy human involvement.[41] The ability to autonomously conduct rendezvous and docking in preparation for servicing operations with minimal human-in-the-loop intervention is a significant factor in accelerating the safety, efficiency, and cost-effectiveness of a commercial ISAM services market.

Standards development is well on its way for ISAM activities, primarily due to efforts within Consortium for the Execution of Rendezvous and Servicing (CONFERS). The International Standards Organization ("ISO") published the first international standard for on-orbit servicing in July 2022. This standard, ISO 24330,[42] "*Space systems — Rendezvous and Proximity Operations (RPO) and On Orbit Servicing (OOS) — Programmatic principles and practices*," is based on CONFERS principles and operating practices.[43] Current work for additional commercial ISAM standards is being conducted for interoperability, refueling, and fiducial markings for client satellites.

The development of standardized interfaces for fluid, power, and data transfer in the near term will enable service providers to perform planned, routine maintenance for an ever-growing market of potential beneficiaries.[44] The first on-orbit fuel sale agreement has already been made, with Orbit Fab's Rapidly Attachable Fluid Transfer Interface (RAFTI) providing refueling capability alongside the RPOD capabilities of the Life Extension In-Orbit (LEXI) servicer of Astroscale U.S. in 2023.[45] Together, these technologies will enable station-keeping, altitude control, and orbital relocation services that can drastically extend the useful life of space assets while reducing operating costs. Defense operators already value such capabilities to enable threat avoidance maneuvers.[46]

Overall, the next five years will see ISAM missions support infrastructure development for NASA programs like Lunar Gateway and Artemis while technological development and standards are spread to the broader industry.

ii. Ten-Year Outlook: A Coexistence Emerges.

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[41] *Id.*
[42] Int'l Org. Standards, ISO 24330:2022 (July 2022), https://www.iso.org/standard/78463.html.
[43] *CONFERS Recommended Design and Operational Practices*, CONSORTIUM EXECUTION RENDEZVOUS & SERV. OPERATIONS (Oct. 2021), https://www.satelliteconfers.org/wp-content/uploads/2021/11/CONFERS_Operating_Practices_Revised-Oct-21.pdf.
[44] *Id.* at 7-8.
[45] *Astroscale U.S. + Orbit Fab Sign The First On-Orbit Satellite Fuel Sale Agreement*, *supra* note 38.
[46] Alec J. Cavaciuti, et al., *supra* note 21, at 10.

In the next ten years, ISAM missions will shape how systems are designed and how the orbital environment is maintained.

The proliferation of modular designs for space systems – that is, standardized system-wide and component-level constructions, producing spacecraft designed to be repaired, reconfigured, replaced, and upgraded on orbit -- will define the mid-term growth of the market to streamline ISAM activities and spur the development of ADR capabilities. As the ISAM market matures and more operators across the space enterprise encompass modular spacecraft and component designs with a robust infrastructure of life extension services, global ISAM industry revenues are expected to increase from $1.67 billion in FY27 to $2.3 billion by FY31.[47] Assembly, manufacturing, and upgrading of space assets will become more vital services offered by a broader range of operators and allow for a secondary market of servicing legacy space objects or assets limited by a lack of fuel but otherwise functional.[48]

Along with the rise in modular designs, it is expected that certain ISAM service providers will develop the capacity to reliably reduce the tumble rate of debris objects to acceptable levels for safe docking. This would enable widespread, cost-effective debris removal activities, without which the long-term growth of the debris population will compromise the utility of strategically advantageous orbital regions.

C. Economic Conclusions and Avenues for U.S. Leadership.

Commercial ISAM operators are here, with global revenues already exceeding $424 million. They have invested in technology, and it is time for the United States to invest in them. The Commission should support the establishment of widely accepted terminology and norms of behavior related to the practice; these will be critical in determining an industry-wide understanding of how to conduct ISAM activities. Again, CONFERS can be a focal point for dialogue with the ISAM industry as the group has agreed on both terminology and best practices. Additionally, as the following sections will explore, the Commission can best support this new economy by providing regulatory clarity of the environment in which it must operate.

III. ISAM Missions and Spectrum Use.

As a prominent spectrum manager likes to joke, there are two things needed for a satellite: gravity and spectrum.[49] While lighthearted, there is wisdom in these words. Spectrum use and access are how satellites communicate while in the void of space. This section will explore three main topics that feed into

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[47] Alec J. Cavaciuti, et al., *supra* note 21, at 10.
[48] *Id.*
[49] Full credit to for this joke goes to Beau Backus, currently serving as the Senior Spectrum Manager at John Hopkins Applied Physics Laboratory.

each other: technical specifics of spectrum use by ISAM missions, the correct radiocommunication service or allocations for ISAM use, and how ISAM spectrum use should be protected and can be coordinated.[50]

A. Technical Spectrum Needs of ISAM Missions.

The Commission generally inquires about the overall requirements for spectrum of ISAM activities.[51] ISAM missions have technical underpinnings that differ from traditional communication or Earth observation satellites.[52] Whether performing servicing, assembly, or manufacturing, ISAM spacecraft will generally engage in proximity operations; and some also may move between orbits and manipulate objects in space. This section will highlight spectrum use by sensors and spectrum use for radiofrequency communications, concluding that the Commission must ensure ISAM missions are authorized for intermittent high bandwidth and power operations alongside low bandwidth and power operations.

i. Diverse Sensors Support ISAM Mission Operations.

The Commission notes that the use of sensors and imaging equipment aboard ISAM missions may have different spectrum needs, distinct from typical conditions for telemetry, tracking, and command (TT&C) operations.[53] Indeed, ISAM missions commonly host normal communications hardware and sensors onboard a spacecraft.[54] Speaking first to sensor suites, the instruments of general use (non-exhaustive) are:[55]

(1) Visible, electro-optical cameras. These sensors are typically used in pairs ("stereo") and are employed for proximity operations at minimal separation. A servicer spacecraft would employ visible sensors from approximately fifty meters to one centimeter away from a client. These cameras operate at wavelengths from approximately 480 – 670 nanometers, or in the visible spectrum.

(2) Light Detection and Ranging (LiDAR). LiDAR is one of the first instruments turned on during proximity operations and is used throughout approach. LiDAR use for servicing begins when the servicer is approximately two kilometers from the client.[56] Current LiDAR ranges operate in wavelength ranges between 400 – 800 nanometers.

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[50] ISAM NOI, *supra* note 1, at ¶¶ 12-14.
[51] *Id.* at ¶ 12 ("What are the overall requirements for spectrum for these ISAM activities?").
[52] *See* Alec J. Cavaciuti, et al., *supra* note 21, at 1-2.
[53] ISAM NOI, *supra* note 1, at ¶ 13.
[54] *Id.*
[55] *See, e.g.*, ARNEY & SUTHERLAND, *supra* note 2 at 13.
[56] *See* FARZIN AMZAJERDIAN ET AL., AM. INST. OF AERONAUTICS AND ASTRONAUTICS, ADVANCING LIDAR SENSORS TECHNOLOGIES FOR NOTEX GENERATION LANDING MISSIONS 7 (2015), https://ntrs.nasa.gov/api/citations/20150006846/downloads/20150006846.pdf.

(3) Infrared sensors. A spacecraft may employ a single or paired infrared (IR) sensors. IR sensors are an "in-between" instrument for proximity operations, providing data when a servicer is between 1.5 kilometers and fifty meters from a client. The IR sensors used to date operate in the mid-wave infrared, approximately 5 – 15 micrometers.

(4) Space-based radars or radiolocations. A spacecraft may employ these sensors to enable proximity operations between a servicer and a client.

ISAM missions in the near future may also employ hyperspectral sensors. Hyperspectral sensors would be useful for the identification of debris materials. As will be discussed in the following subsection, ISAM use of sensors will require bandwidth for downlinking payload (sensor) information beyond traditional TT&C use.

ii. ISAM Operations Have Bandwidth Requirements that Vary by Mission Phase.

ISAM missions will have varying bandwidth requirements throughout the mission lifetime.[57] During phases of proximity operations – such as inspection, prior- or post-docking, and potentially multi-craft assembly or manufacturing activities – larger bandwidth will be required for higher rates. This is because these operations require live communication of sensor data to support operations.[58] For instance, during rendezvous and docking operations, the Astroscale Ltd. ("Astroscale U.K.") ELSA-d mission required up to approximately 8.5 MHz of bandwidth, with an 8 Mbps link rate. The bandwidth requirements for Astroscale's upcoming LEXI mission are similar.

It should be noted that for future missions, including Astroscale missions, the ability to downlink at higher bandwidths and resultant high data rates are highly beneficial. For instance, downlinking high-rate video and other sensor data for inspection, rendezvous, and proximity operations requires higher bandwidths and data rates. Astroscale U.K.'s future NGSO servicer, ELSA-M, is planning to use high-resolution imaging sensor data, typically requiring up to 100 Mbps data rates.

ISAM mission bandwidth requirements during proximity operations and active sensor use can be juxtaposed with bandwidth requirements during the other mission phases. When no proximity operations are ongoing – for example, after a successful docking – and no live sensor use is required, ISAM missions will have diminished bandwidth requirements. This is because the majority, if not the whole, of communications during these operational modes is limited to TT&C uplink and downlink. For these "static" modes of operation, the bandwidth downlink and uplink are expected to have data rates in the tens of kbps

[57] ISAM NOI, *supra* note 1, at ¶ 12 ("What are the bandwidth requirements?").

[58] Similar bandwidth requirements can be expected when ISAM operations are actively utilizing sensors unless data is stored to downlink gradually later.

to less than 5 Mbps. Using ELSA-d as illustrative once more, TT&C operations used an approximately 5 - 256 kHz bandpass, with 5-115 kbps uplink and downlink.

iii. Power Requirements for ISAM Communications Vary with Mission Phase.

Alongside bandwidth requirements, the Commission asks about the power requirements of ISAM missions.[59] The main driver for the downlink radiofrequency signal power for GSO and NGSO ISAM missions is downlinking sensor data and other safety telemetry during RPO operations.

The power requirements for ISAM missions differ from traditional satellite missions in that the required signal power varies greatly depending on the phase of the mission.[60] Traditional satellites require occasional low-rate uplink and high-rate downlink of stored data (imaging missions) or continuous high-rate uplink and downlink (communications missions) throughout their operational lifetimes. In contrast, ISAM missions require constant low- to medium-rate uplink and high-rate downlink during rendezvous and docking and occasional low-rate uplink and downlink during the servicing and solo flight phases of the mission. The Commission should ensure ISAM spectrum communications are authorized at proper power levels, up to those required for high-rate downlinks during RPOD phases.

iv. 1 to 8 GHz Are Frequency Ranges Optimal for Supporting Bandwidth Requirements.

Understanding the difference between bandwidth and power requirements for ISAM missions actively communicating sensor information versus "static" modes, this section can turn to a consideration of spectrum needs.[61] Traditionally, sensor information – such as for Earth imaging – is downlinked in high frequencies. These frequency ranges can more easily accommodate higher bandwidth and power ranges to accomplish high data rate transmissions. However, as with all higher frequencies, beginning primarily with Ku-band, rain fade becomes a problem. Thus, trade between higher data rates and link availability needs to be evaluated on a mission-by-mission basis.

Higher frequencies for sensor (payload) data transmission are also preferred for ISAM operators.[62] Communication links during RPOD, or when payload downlink is otherwise required, are best

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[59] *Id.* at ¶ 12 ("What are the power requirements?").
[60] *Id.* at ¶ 12 ("To what degree are the needs short-term or episodic, or to what degree are the needs for "always-on" transmissions and reception?").
[61] *Id.* at ¶ 13.
[62] ISAM missions may make use of the X-band. However, as will be discussed *infra*, the common allocations in X-band (Earth-exploration Satellite Service) are not a well-fit radiocommunication service for ISAM missions, and the X-band is already heavily used by Earth observation systems and government agencies. *See* Charles A. Cooper, Off. Spectrum Mgmt., *The Spectrum Needs of U.S. Space-based Operations: An Inventory of Current and Projected Uses*, NAT'L TELECOMMS. & INFO. ADMIN. A-22 toA-26 (July 2021), https://www.ntia.doc.gov/report/2021/spectrum-needs-us-space-based-operations-inventory-current-and-projected-uses.

accomplished in C-band or above. TT&C operations can be accommodated in even lower frequency ranges, such as the S-band.[63] However, the frequency ranges for TT & C links should stay within 1 GHz.[64] Overall, the optimal range for ISAM satellite system operations – or space operations – is 1 to 8 GHz.[65]

v. Transmission Frequency Can Be Categorized by ISAM Mission Stage.

This section will summarize transmission frequency needed by the mission phase.[66] While most operational information is known for performing servicing missions, suggestions for assembly and manufacturing needs will also be made.

Proximity operations generally. During proximity operations generally – including inspection, rendezvous, approach, docking, etc. – continuous communication is needed. Proximity operations can be understood when the switch from absolute to relative navigation occurs; for servicing missions in GSO, this is currently baselined around 2 kilometers separation between client and servicer.

Continuous communications support live command and control, as opposed to "canned" commanding. The duration of continuous communication is estimated to be twenty-four hours for nominal operations. In the event of an abort or reset, communications may have a longer duration; alternatively, they may cease and restart if lighting constraints dictate when another approach can be made. The requirement of constant communication during proximity operations will be true of most ISAM missions unless they are fully autonomous and do not need to downlink imagery to be used by a human during the docking process.[67]

It is offered that assembly and manufacturing missions may also desire continuous coverage any time they are actively assembling or manufacturing an object. This could entail constant communication for more than twenty-four hours.

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[63] Noted again *infra*, it must be stated that use of the 2 GHz space operation service allocation (both 2025-2110 MHz and 2200-2290 MHz) is very challenging due to significant use by existing and planned NGSO and GSO systems. These frequency bands are heavily congested and obtaining coordinated access on a reliable and robust basis to operate resilient TT&C is very challenging and excessively onerous.

[64] *See* ITU-R, SA.363-5, *Space Operation Systems*, ITU at 7 (Mar. 1994) (discussing conditions that affect tracking accuracy for space missions, and concluding that "[I]t may be assumed from the point of view of tracking accuracy most application missions require frequencies above 1 GHz.").

[65] *Id.* at 8 ("In summary, the preferred frequencies for space operations lie approximately between 1 and 8 GHz. Lower frequencies may be used, particularly for…missions which do not call for high-precision tracking. Higher frequencies may be preferred for space operation functions of spacecraft using these frequencies as well for mission links with the Earth.").

[66] ISAM NOI, *supra* note 1, at ¶ 13.

[67] For instance, LEXI will be largely autonomous, but still downlink imagery to ensure there is a human in the loop for go/no-go decisions during proximity operations.

Post-docking operations. For a short period after docking operations, continuous telemetry downlink is employed to ensure attitude control and station-keeping are proceeding nominally and validate altitude control and station-keeping algorithms. As docking operations become more routine, this post-docking "check-up" requirement may diminish.

Normal operations – combined stack or solo flight. Communication needs are minimal during normal operations of an ISAM spacecraft, such as station-keeping after docking or waiting in a parking orbit between clients. This phase has similar telemetry communication requirements as standard satellites in a given orbital regime.

Relocation operations. Relocation operations can include inclination corrections, repositioning a client for service, retirement to graveyard (GSO), placement into a decaying orbit (NGSO), and more. During these operations, communication requirements vary depending on the needs of the customer and interference analysis and coordination as each operation is planned.

Constant communications are assumed to be generally needed for initial maneuvers to enter or exit the GSO arc. Additionally, if a customer is permitted to leave their spacecraft in operation during an inclination reduction, the communication requirements are near-constant to ensure continuous pointing accuracy. However, during retirement to graveyard or repositioning a client when the client is not in operations, only minimal communication for the basic health and safety of the servicer are needed.

Departure operations. When a servicer spacecraft leaves a client, the general requirement of constant communication during proximity operations will apply. However, the duration of the communication – or timing margin – needed will be diminished, as this phase does not need to account for aborts. Payload downlinks can be expected until a servicer exits the client's proximity.

Refueling and refurbishing operations. During refueling operations, it is expected that high data rates and bandwidth will be needed for the entire refueling operation. The continuing transmission is required to monitor aspects of both vehicles in much greater detail than usual. The same requirement is proposed for refurbishing or replacement services, where the health of both vehicles is monitored closely during a part exchange or other service.

vi. Conclusion on ISAM Technical Spectrum Needs.

From the above information, several general conclusions about ISAM mission needs can be called out. First, it will be common for ISAM missions to have a complement of spacecraft sensors. Sensor or payload communications will require spectrum with higher bandwidth and power, compared to "static" or solely TT&C operations, which can operate at lower bandwidths and power levels.

Second, "typical" ISAM mission operations will vary between times of low bandwidth and data rate requirements, when interference may be acceptable, to times of high bandwidth and data rate requirements, when interference cannot be tolerated.[68] Interference during times of high bandwidth and data rate requirements – when proximity operations are being performed – will obstruct safety-critical operations and endanger both the client and servicer spacecraft.[69]

Finally, ISAM missions would be technically enabled by using frequencies between the S- and X-bands[70]. The upper limit is bounded by frequency propagation characteristics and the size, weight, and power ("SWaP") analysis of a mission. For example, it would be rare for a GSO servicer spacecraft to approach the size of traditional GSO spacecraft; this reduction makes it unfeasible to carry hardware for communications above Ka-band frequencies. The Commission should be mindful of the relationship between spacecraft and communications hardware when selecting frequencies for ISAM mission operations.[71]

B. ISAM Missions Through the Lens of Radiocommunication Services.

Within this NOI, the Commission is attempting to define attributes of three new types of space operations – servicing, assembly, and manufacturing – under one umbrella. The breadth of ISAM makes defining "typical" spectrum use for all missions exceedingly difficult and will likely result in a definition of poor fit.[72] However, it *is* possible to evaluate the correct radiocommunication service for all ISAM at the same time. ISAM communications are undertaken to grow space-based infrastructure, and as will be demonstrated, this sector of operations is not intentionally contemplated by any existing radiocommunication service.

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[68] At this time, Astroscale proposes that the Commission continue to evaluate "typical" spectrum use on a mission-by-mission basis as the archetypes of ISAM continue to develop. The breadth of ISAM makes defining "typical" spectrum use for all missions exceedingly difficult and will likely result in a definition of poor fit. Instead, "typical" use investigations should: (1) average the time spent in each operational mode across a spacecraft's lifetime, and (2) consider the directionality of the connection. While ISAM missions today use traditional space-to-Earth or Earth-to-space links, is it anticipated that near-term missions will also employ space-to-space communications, as well as localized connections, such as WiFi. Providing both pieces of information to determine a spacecraft's "typical" spectrum use will support the Bureau staff in determining how the orbital spectrum environment is impacted and enable appropriate licensing decisions.

[69] ISAM NOI, *supra* note 1, at ¶ 13 ("Is it reasonable to continue in some instances to authorize communications supporting ISAM capabilities on a non-interference, unprotected basis, particularly where the communications may be critical to conduction an RPO mission for example, or something similar?").

[70] *Id.* at ¶ 13 ("[W]hat frequency ranges would be most viable to support these missions based on current technology and mission requirements,…").

[71] *Id.* at ¶ 14.

[72] *Id.* at ¶ 13.

Broadly, the International Telecommunication Union (ITU) defines many types of radiocommunication services.[73] Each identified radiocommunication service is assigned allocations or frequency band(s) for use by that type of service.[74] Under this allocation regime, non-conforming use of radio frequencies may only be authorized on an individual and unprotected basis.[75] Therefore, an operator wishing to uphold worldwide spectrum coordination and enjoy interference protection[76] must identify the proper radiocommunication service and corresponding frequency for their mission's use.

It is this first step – identification of a proper radiocommunication service – where ISAM missions hit a roadblock. ISAM spacecraft must operate in one of the several radiocommunication services specific to satellites.[77] But none of the currently defined satellite services appear to be a proper fit, definitionally, to the operations of commercial ISAM missions.[78] Of the satellite services, three warrant specific analysis for ISAM: space operation service (SOS), fixed-satellite service (FSS), and Earth exploration-satellite service (EESS).

Space Operation Service. The space operation service is defined as "[a] radiocommunication service concerned exclusively with the operation of spacecraft, in particular space tracking, space telemetry, and space telecommand."[79] A definitional note adds that, "[t]hese functions will normally be provided within the service in which the space station is operating."[80]

[73] ITU Radio Regulations, Article 1.19 (2022).
[74] *Id.* at Article 1.16; *see ITU Regulatory Framework for Space Services*, ITU 2, https://www.itu.int/en/ITU-R/space/snl/Documents/ITU-Space_reg.pdf (last visited Oct. 16, 2022).
[75] *See* 47 C.F.R. § 2.102(a),(b) (specifying that authorized uses of frequencies for radiocommunication shall be in accordance with the Table of Frequency Allocations); *id.* § 2.106 (Table of Frequency Allocations).
[76] *See Id.* § 2.104(d) (listing categories of services and allocations, including prescriptions on stations of a secondary service).
[77] *See* ITU Radio Regulations, Article 1 Section III (2022) (defining radio services, and noting that – unless otherwise stated – any radiocommunication service relates to terrestrial radiocommunication).
[78] As noted by the Aerospace Corporation, the space research service may be used for ISAM in a technology development phase. *See* Comments by the Aerospace Corporation, IB Docket Nos. 22-271 & 22-272 at 12-3 (filed Oct. 21, 2022). However, as will be discussed below, demonstration missions would be appropriately authorized under Part 5 of the Commission's authority. *See, e.g.,* 47 C.F.R. § 5.64 (2022) (listing special provisions that apply to licensing experimental satellite systems). Additionally, experimental systems are not allowed to cause interference to any station operating in accord with the Table of Allocations. *See Id.* § 5.84. Astroscale supports use of the space research service for experimental applications as desired. However, this Comment is predominately concerned with enabling *commercial* operations and the future of the space economy, the space research service is not considered as an eligible radiocommunications service. The undesirability of the space research service as a commercial solution is compounded by the fact that all primary downlink allocations are either largely inaccessible in the U.S. (S-band), or subject to degradation of propagation characteristics (25 and 37 GHz). *See* Aerospace Comments, *supra* note 78, at 17-8.
[79] ITU Radio Regulations, Article 1.23 (2022); 47 CFR § 2.1(c) (2022).
[80] ITU Radio Regulations, Article 1.23 (2022) (at sentence 2).

The Commission inquires whether typical usage for ISAM missions could be considered a space operation service.[81] As currently defined, the SOS may be one of the best, if not the best, definitional fit with the spectrum use of ISAM missions.[82] ISAM missions spend a large percentage of total transmission time passing spacecraft maintenance telemetry – including separation deployments, optical measurements, and inertial measurements – as well as commanding.[83] Additionally, the SOS includes tracking, or spectrum use for spacecraft orbit control systems, surveillance, safety, and recovery, orbital accuracy, and/or attribution of location data to mission measurements and observations.[84] This delineation of tracking coincides nicely with a significant characteristic of ISAM missions: performing rendezvous, and potentially docking. In total, the defined SOS could well cover the space tracking, commanding, and telemetry needs of ISAM missions.[85]

One intermittent aspect of ISAM operations that the SOS does not appear to cover is payload transmissions. As discussed above, ISAM operations to date and in the future may use an array of onboard sensors to support the overall mission objective.[86] It seems that the SOS, as currently conceived, would be a proper service to transmit payload data, such as images.[87] However, this could be remedied with a definitional tweak or intermittent guidance from the Commission.

Fixed-Satellite Service. The fixed-satellite service is "[a] radiocommunication service between Earth stations at given positions, when one or more satellites are used; …; the fixed-satellite service may also include feeder links for other space radiocommunication services."[88]

The FSS is the second-best contender for ISAM operations to fit under an existing radiocommunication service. ISAM operations, especially those in NGSO, communicate between multiple

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[81] ISAM NOI, *supra* note 1, at ¶ 13 ("We seek comment on whether typical usage for ISAM missions could be considered a space operations service as currently defined.").
[82] *Id.*
[83] *See* SA.363-5, *supra* note 64, at 2.1 & 2.2 (describing "maintenance telemetry" and "telecommand" as used by the space operation service).
[84] *Id.* at 2.3 (listing subsystems of tracking).
[85] *See* Comments by the Aerospace Corporation, *supra* note 78, at 12.
[86] *See* Astroscale Holdings Inc., *Elsa-d Press Kit*, 5 (2021), https://astroscale.com/wp-content/uploads/2021/08/ELSA-d-Press-Kit-2021.pdf; Space Logistics LLC, *Technical Appendix,* IBFS File no. SAT-LOA-20191210-00144 at 2-6 (2020) (stating that MEV-1 and MEV-2 are practically identical, utilizing the same suite of sensors)[*hereinafter* MEV-2]; Turion Space Corp., *Technical Annex*, IBFS File No. SAT-LOA-20220526-00055 at 1 (2022); Spaceflight, Inc., *Application Narrative,* IBFS File No. SAT-LOA-20220111-00007 at 20 (Jan. 11, 2022).
[87] Technically, some payload data may also be large enough that it would be optimal to downlink it in a higher frequency, as the highest international SOS allocation is ends at 2290 MHz. Allocation of Spectrum for Non-Federal Space Launch Operations, *Report and Order*, FCC 21-44; 86 FR 33902 (June 28, 2021). *See* Aerospace Comments, *supra* note 78, at 12.
[88] ITU Radio Regulations, Article 1.21 (2022).

(currently fixed) ground stations to support spacecraft operations.[89] And, because there is no specific requirement on what kind of information FSS systems transmit, ISAM operations can be covered under this definition.[90] Indeed, currently MEV-1 and MEV-2 use conventional and extended C- and Ku-band FSS allocations to operate.[91]

With that said, it is still being determined whether FSS is *the* appropriate home for ISAM missions. The FSS is arguably most efficient for communications that employ multi-casting, require extensive geographic coverage, and/or seek to move large amounts of data.[92] While ISAM missions may require ample geographic coverage for mission operations, this is not intended to affect "communications" across large geographic regions. Additionally, ISAM missions are only affecting point-to-point communications to support *space-based operations*, not as a type of communication meant to enrich Earth-based persons.

Earth Exploration-Satellite Service. The Earth exploration-satellite service is "[a] radiocommunication service between Earth stations and one or more space stations, which may include links between space stations, in which: information relating to the characteristics of the Earth and its natural phenomena, including data relating to the state of the environment, is obtained from active sensors or passive sensors on Earth satellites;…."[93]

The FCC should clarify whether any ISAM missions qualify to use the EESS under appropriate technical conditions. Most ISAM operations are focused on a space-based infrastructure, but some missions may capture Earth imaging coincident with the primary mission objective.

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[89] NGSO ISAM operations have used twelve ground stations to support operations as the spacecraft circle the globe. *See* Denali 20020, Inc., *Application Narrative*, IBFS File No. SES-STA-20200113-00043 at 14-16 (2020); Center for Southeastern Tropical Advanced Remote Sensing, *Application Narrative*, IBFS File No. SES-STA-20200811-00859 at 14-16 (Aug. 12, 2020); Viasat, Inc., *Application*, IBFS File No. SES-STA-20200117-00055 (2020). GSO ISAM operations use fewer ground stations, as the servicer is stationary relative to a fixed point. MEV-1 and MEV-2 only used a total of eight ground stations to support operations. Space Logistics LLC, *MEV1/MEV2 Ground Station Notification*, IBFS File No. SAT-LOA-20170224-00021 at 2 (Sept. 30, 2021).

[90] *See* Joseph N. Pelton, *Space Telecommunications Services and Applications*, in HANDBOOK OF SATELLITE APPLICATIONS 73, 88 (Joseph N. Pelton et al., 2d eds.) (2017) (Table 2, listing examples of FSS applicated divided by generic service category).

[91] *See, e.g.*, MEV-2, *supra* note 86; Space Logistics LLC, *Application Narrative*, IBFS File No. SAT-LOA-20170224-00021 (Feb. 24, 2017) [*hereinafter* MEV-1].

[92] *See* Joseph N. Pelton, *Space Telecommunications Services and Applications*, in HANDBOOK OF SATELLITE APPLICATIONS 73, 90 (Joseph N. Pelton et al., 2d eds.) (2017) (listing "the most efficient FSS satellite applications" as: (1) television distribution over broad areas, (2) communications services to rural and remote areas, (3) communication services to islands with small populations, (4) communication services to large-scale networks over broad areas, (5) multi-casting, and (6) short-term events or remote news gathering"); *see also* Aerospace Comments, *supra* note 78, at 13 (noting FSS is not a true match for ISAM TT&C or non-TT&C use, as "it is not related to communications between Earth stations").

[93] ITU Radio Regulations, Article 1.51 (2022); 47 CFR § 2.1(c) (2022).

In sum, ISAM spectrum operations do not have a perfect definitional fit with any presently-defined radiocommunication service.[94] The FCC should continue to authorize commercial, non-demonstration ISAM missions in the FSS or SOS until a service of better fit is located.[95] Of the options, they are the current radiocommunication services of the best definitional fit for commercial ISAM missions. Additionally, as relayed in the technical details above, the optimal frequency range for ISAM mission communications is approximately 1 – 10 GHz.[96] This range overlaps with significant allocations in the SOS and FSS, specifically worldwide primary allocations for SOS in the 2 GHz range[97] and primary commercial-use allocations to the FSS in C-band.[98]

Astroscale urges the Commission to accommodate feeder links for ISAM sensor data and TT&C for ISAM missions in current FSS allocations. Astroscale believes it should be possible under the present ITU Radio Regulations.

i. The United States Must Engage Internationally to Secure ISAM Spectrum.

It has been demonstrated that there is no clear home for ISAM mission spectrum use under the international regime. The FCC should motivate the U.S. delegation to the 2023 World Radiocommunication Conference (WRC23) to progress on the issues of ISAM spectrum identification and use. For instance, a recent Topic was proposed with a partial near term solution, identifying FSS bands as a place for in-orbit servicing feeder links,[99] but the U.S. delegation opposed this effort. Parallel to international engagement, the U.S. could also seek to create a footnote to the Table of Allocations at WRC23, denoting bands – such as those allocated to FSS – where ISAM spectrum use may be authorized.[100]

Astroscale believes it should be possible to incorporate ISAM into the existing spectrum environment at WRC23. If the United States cannot successfully advocate for the national ISAM industry at WRC23, ISAM operators will remain vulnerable to regulatory uncertainty, and significant investment losses may be

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[94] *See* Aerospace Comments, *supra* note 78, at 14 (noting "the lack of ITU radio service definitions inclusive of all ISAM use cases").

[95] *See* ISAM NOI, *supra* note 1, at ¶ 13 ("What services, as defined by the ITU Radio Regulations and the Commission's rules, are most critical for ISAM capabilities?").

[96] It should be noted that this is for downlink and uplink communications. No conclusions are reached about optimal frequencies for space-to-space communication, localized or not.

[97] It should be noted that these allocations are largely inaccessible by commercial systems. *See* 47 C.F.R. § 2.106 (2022) (denoting S-band space operation service allocations for Federal use).

[98] *Id.*

[99] *See* Ofcom, Call for Input, *UK Preparations for the World Radiocommunication Conference 2023 (WRC-23): UK Provisional Views and Positions for WRC-23* at 34 (released June 24, 2022), https://www.ofcom.org.uk/__data/assets/pdf_file/0025/239407/WRC-23_Call_for_Input.pdf.

[100] *See, e.g.,* Dr. LiChing Sung, *Spectrum Management Tools: Radio Regulations and Table of Frequency Allocations*, NAT'L TELECOMMS. & INFO. ADMIN. at 16-20, https://ustti.org/wp-content/uploads/2019/11/Day-1-4_RR-and-allocations-table_20190903.pdf (last visited Oct. 24, 2022) (discussing sovereign footnotes and their uses in the ITU's Table of Allocations). Astroscale understands that such a measure could be seen as drastic at the international forum, and offers it primarily to demonstrate paths of advocacy that can be pursued and concluded in line with WRC23.

realized. As a last resort, the FCC could model international advocacy for a WRC27 Agenda Item on similar work undertaken for lunar communications.[101]

The FCC should also engage with regional groups, such as the Inter-American Telecommunication Commission (CITEL) and the European Conference of Postal and Telecommunications Administrations (CEPT), to coordinate ISAM and spectrum access recommendations.

C. For ISAM Mission Phases Requiring Spectrum Protection, Coordination Mechanisms Will Facilitate Inclusion.

The above subsections have asserted two predominant facts. First, due to the technical operations of ISAM missions, there will be two common modes of communication – a low-bandwidth, low-power link primarily for routine phase TT&C that may tolerate intermittent interference, and a high-bandwidth, high-power link that cannot tolerate interference, as it supports live commanding during critical proximity operations. Second, the SOS and FSS are the existing services best fit to accommodate commercial ISAM missions. This subsection will affirm that commercial ISAM missions can participate in the current spectrum environment with minimal interruptions, even adjusting the need for protection in some mission phases.

i. ISAM Missions Need Spectrum Interference Protection at Certain Mission Phases.

First, it must be re-emphasized that ISAM missions, at some point in their operations, require spectrum priority for interference-free communications.[102] These times include proximity operations, rendezvous, and docking – whether with an uncrewed or crewed spacecraft, departure operations, and other operations that carry heightened risk and may require live commanding. At these critical points, experiencing spectrum interference could result in spacecraft damage, catastrophic failure, or even danger to spaceflight human participants and astronauts.

The Commission must recognize that ISAM missions require episodic, if not enduring, spectrum priority. Furthermore, when an appropriate radiocommunication service is identified or created, ISAM operators should benefit from the certainty provided by the delineations between primary, secondary, and out-of-band use, just as all other satellite operators today enjoy already.

ii. Various Mechanisms Support Coordination of ISAM Operations with Other Operators.

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[101] *See International Bureau Seeks Comment on Recommendations Approved by the World Radiocommunication Conference Advisory Committee*, Public Notice, DA 22-954, at Appendix B (Sept. 16, 2022).

[102] ISAM NOI, *supra* note 1, at ¶ 13 ("Is it reasonable to continue in some instances to authorize communications supporting ISAM capabilities on a non-interference, unprotected basis, particularly where the communications may be critical to conducting an PRO mission for example, or something similar?").

ISAM missions have several strategies that could be used to facilitate their entrance into the existing spectrum environment, from synergies to coordination mechanisms. This section will explore two sharing tools that would facilitate ISAM mission use of FSS allocations and offer general geographic and temporal considerations to enable coordination.

Astroscale urges the Commission to accommodate commercial ISAM missions in current FSS allocations for two reasons related to sharing.[103] First, a large portion of potential ISAM clients operate in FSS allocations – these include NGSO constellations, candidate clients for end-of-life services, GSO telecommunications satellites, candidate clients for life extension, inclination correction, and more. Where it is possible, "piggybacking" spectrum use in a client band is an efficient sharing mechanism, and both the servicer and client have the incentive to coordinate those operations.[104]

The second reason is best explained conceptually. Imagine placing a boulder into a stream and a river, respectively. For the stream, such an interruption forces the water to reroute significantly, as there is a limited path (streambed) along which the water can flow. However, upon placing a boulder in a river, there would be no noticeable change in the path – the boulder is not significant enough to diverge the river and only displaces a small *volume*.

FSS allocations can accommodate ISAM missions in an analogous way to a river being uninterrupted by a boulder. Regarding technical operational capacity, there are significant pathways (bandwidth) and assets for FSS communications to diversify communication pathways.[105] When an ISAM mission requires interference-free communications, FSS operators may reroute communications volume around the temporary disturbance[106] more easily than operators in other radiocommunication services with limited bandwidth.[107]

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[103] *Id.* at ¶ 14 ("To what extent is sharing with other operators, both federal and commercial, possible, depending on the type of ISAM mission?").

[104] *See* MEV-2, *supra* note 86, at 11 ("Space Logistics will coordinate with Intelsat and operate on a subset of the frequencies [already] authorized to and coordinated for IS-1002");; *see also* Aerospace Comments, *supra* note 78, at 14 (noting "piggybacking" in a client's spectrum is likely more appropriate for the FSS than other specialized services). However, the Commission *must not* require spectrum piggybacking. When possible, this is a good tactic, as it does not alter the already-coordinated spectrum environment. However, this is not a long term solution. For multi-client servicers, it is naïve to think that the servicing entity will always know their client – and client's frequencies – enough in advance to impact the servicer's design. It is time to build for the future, to build resilient networks, and to not create a negative feedback loop in ISAM's attempts to access spectrum. While ISAM operations can share with a client – when there is one – this is a best practice that can only practically hold for those servicers designed and launched with a specific client in mind.

[105] *See* Aerospace Comments, *supra* note 78, at 19-20 (noting "[t]here are nearly three dozen fixed-satellite service allocations below 90 GHz").

[106] This would also be supported by other sharing mechanisms, such as geographic coordination.

[107] In the future, it is foreseeable that ISAM operators could purchase capacity from an FSS operator, and route traffic through a space-to-space link, with the FSS provider then completing uplink and downlink. ISAM operators therefore also represent a potential customer for FSS operators. ISAM NOI, *supra* note 1, at ¶ 14 ("What are the pros and cons of any necessary operational changes, and how do those affect the cost and viability of ISAM missions?").

Beyond sharing considerations by radiocommunication service, there are general spectrum coordination mechanisms that ISAM operators can employ.[108] Geographic separation is one sharing mechanism that would be relatively easy to deploy, especially for missions that require minimal Earth stations.[109] The other readily-available sharing mechanism is time and traffic separation – if a servicer needs to dock with a GSO client, the proximity operations could be correlated with periods of low-system loads for neighboring satellites when spectrum may be more available.[110] Overall, there are several sharing mechanisms that ISAM mission operators can investigate to determine optimal fit with mission design while synonymously ensuring the efficient and economical use of spectrum.

Finally, it should be highlighted that ISAM missions can contribute to coordination and the spectrum environment by removing objects.

D. ISAM Technical Needs – Conclusions.

Several conclusions must be called out from the above discussion.

- ISAM missions use a range of sensors for operations; high bandwidth and power is needed for these communications.
- There are critical stages of ISAM operations when interference cannot be tolerated and would detrimentally impact live commanding necessary for spacecraft safety. The Commission must ensure these stages are protected from harmful interference.
- The FSS and SOS are radiocommunication services of best fit for ISAM, presently; the Commission must enable access to these services, which have allocations matching the technical needs of ISAM missions.
- ISAM operators can engage in coordination mechanisms like piggybacking on client spectrum and temporal or geographic separation.

Understanding the spectrum background of ISAM missions, the next section will dive into licensing considerations in the United States.

IV. United States Commercial Licensing and ISAM: A Pathway to Be Improved.

There is one major challenge that faces would-be regulators of ISAM activities. This challenge exists not only at the national level but also at the international level. This is a challenge that goes to the very foundation of what building for ISAM means – it is the challenge of instituting new infrastructure.

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[108] *Id.* at ¶¶ 13, 14 ("Are there conditions that could facilitate coordination with incumbent users, such as geographic or temporal limitations, thereby providing some assurance of interference-free use, even where the status of such operations remains inconsistent with an allocation." "[I]n frequency bands shared with Federal operations, what steps would facilitate sharing? What steps would facilitate sharing in frequency bans shared with terrestrial operations?")

[109] *See* JOHN PAHL, INTERFERENCE ANALYSIS: MODELLING RADIO SYSTEMS FOR SPECTRUM MANAGEMENT 318-19 (2016).

[110] For example, there are generally less demands on a communication system at 3 AM than 3 PM. *See id.* at 323-4.

Satellite spectrum use to date, especially in the commercial sphere, is built on an underlying and generally-applicable assumption that spacecraft provide service from predictable and consistent locations. This fundamental principle served from the launch of the first geostationary communications satellite in 1963[111] and remains largely accurate today. The principle that a spacecraft deploys to a desired orbit and stays there is reflected in various licensing forms for spectrum access around the globe – including in the FCC's license application requirements.[112]

ISAM activities will pressure the current satellite spectrum licensing regime because they challenge the underlying assumption of static orbits. Several types of ISAM will repeatedly move between orbital locations as part of their service provision. The following subsections will discuss the challenges of ISAM activities to current regulations under Part 25, how ISAM operations should satisfy and support orbital debris mitigation showings, and how servicing operations should be authorized.

A. Several Space Station Authorization Challenges Exist Under the Current Regime.

There are several aspects of Part 25 regulations that awkwardly fit, or produce undesirable results, for licensing ISAM missions. This section will explore the benefits of Part 5 and Part 25 as licensing avenues and difficulties for licensing commercial ISAM missions under Part 25.

i. Selection of Licensing Regime – Part 5 and Part 25 Both Hold Value.

At the outset, Astroscale U.S. does not believe any modifications to Part 5 are needed.[113] Part 5 provides a useful path for authorizing experimental operations, as it is intended to do. ISAM operators should remain free to elect to license under Part 5 or Part 25, as is appropriate for their mission.

ii. Part 25 Is Not Designed for ISAM Operations and Presents Challenges to New Entrants.

Commercial ISAM missions have begun licensing under Part 25, and operators seeking authorizations under this part are expected to increase significantly over the next five years.[114] The

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[111] *See* ITU, HANDBOOK ON SATELLITE COMMUNICATIONS HISTORY OF SATELLITE COMMUNICATIONS 2-3 (3d ed. 2015).

[112] *See* 47 C.F.R. § 25.114(c)(5)(i) (2022) (requiring the orbital location requested for space station applications in the GSO); *id.* § 25.114(c)(6)(ii)-(iv) (requiring orbital information for space station applications in the NGSO).

[113] ISAM NOI, *supra* note 1, at ¶ 17.

[114] Momentus and Spaceflight are already licensing OTVs under Part 25. *See* Application of Momentus Space, LLC, IBFS File No. SAT-STA-20211216–00195 (filed December 16, 2021); Application of Spaceflight, IBFS File No. SAT-STA-20210205-00017 (granted May 28, 2021). Turion is seeking authorization for an inspection mission under Part 25. Turion Space Corp., *Legal Narrative*, IBFS File No. SAT-LOA-20220526-00055 at 2 (May 26, 2022). Astroscale U.S. will launch the LEXI mission in 2025, under a Part 25 authorization. Northrop Grumman is anticipated to launch the Mission Robotic Vehicle and Mission Extension Pods in 2024, likely also under a Part 25 license. *See*

International Bureau staff and the applicants have made valiant attempts to fit ISAM authorization under the existing Part 25 regime. However, a plain reading of Part 25 reveals multiple provisions that must be addressed to enable a clear licensing pathway for ISAM missions.[115] This section will explore those provisions.

Orbital regime selection. The choice of licensing *type* is the first difficulty ISAM operators face. Part 25 offers three licenses to pursue: NGSO,[116] GSO,[117] or small spacecraft.[118] Astroscale submits that a small spacecraft authorization[119] will be generally undesirable for most types of ISAM missions – spectrum priority rights are not given,[120] and it is unlikely that ISAM missions will generally comply with the mass requirements.[121]

The choice between NGSO and GSO regimes is complicated for operators that may move between them during a servicer's lifetime. The licensing history of MEV-1 indicates that a servicer that performs operations *outside* and *inside* the geosynchronous arc should be licensed as a GSO.[122] However, conversations at the international level indicate a divorced opinion – that operations in the arc are GSO, and anything else is NGSO.[123] Regardless, identifying even the correct orbital regime to begin licensing is a hurdle for ISAM operators.

Pioneering the Future of Satellite Servicing, NORTHROP GRUMMAN, https://www.northropgrumman.com/space/mission-robotic-vehicle-mrv-satellite-technology/ (last visited Oct. 28, 2022). This is not to mention the commercial space stations that have been announced. The Aerospace Corporation's assertion that "[a]s the ISAM market matures, its activities will no longer be experimental and will move towards operational licensing, *but this is unlikely to be the case for at least the next 5-10 years*" is an affront to the ISAM operators currently seeking Part 25 authorizations, let alone those who will partake in the next five to ten years. *See* Aerospace Comments, *supra* note 78, at 49.

115 ISAM NOI, *supra* note 1, at ¶ 16 ("We seek comment on any updates or modifications to the Commission's licensing rules and processes that would facilitate ISAM capabilities.")

116 *See* 47 C.F.R. § 25.114 (2022) (applications for NGSOs and GSOs).

117 *Id.*

118 *Id.* §§ 25.122, 25.123 (applications for streamlined small space station authorization and applications for streamlined small spacecraft authorization).

119 *Id.*

120 *Id.* §§ 25.122(c)(9), 25.123(b)(7) (2022).

121 Both MEV-2 and Spaceflight Sherpa's do not satisfy the 180 kg wet mass limit for NGSO missions, while ELSA-d is within the margin of error. MEV-2, *supra* note 86, at 26 (weighing 1,525 kg); Spaceflight, Inc., *Revised Orbital Debris Assessment Report*, IBFS File No. SAT-STA-20150821-00060 at 6 (Nov. 2, 2015) (weighing 663 kg); Astroscale Holdings, Inc., *supra* note 86, at 4 (weighing ~175kg); *see* 47 C.F.R. § 25.122(c)(12) (2022).

122 *See* MEV-1, *supra* note 91 (MEV-1 applied as a GSO spacecraft for the entire lifetime, even though initial operations were conducted near graveyard orbit, approximately 300 kilometers away from the geosynchronous arc).

123 *See, e.g.,* ITU Radio Regulations, Article 1.189 (2022) (defining a "geostationary satellite" as a "geosynchronous satellite whose circular and direct *orbit* lies in the plane of the Earth's equator and which thus remains fixed relative to the Earth; by extension, a *geosynchronous satellite* which remains approximately fixed relative to the Earth.").

Dismissal of applications. While the Commission has provided partial guidance on when an ISAM application may be dismissed through prior action, the regulatory landscape remains unclear. Two grounds for potential dismissal must be clarified.

First, the Commission may choose to dismiss an application that is defective in completeness;[124] ISAM operators that are unsure of their deployment orbit, as it may be client specific, but want to begin the licensing processing are faced with a conundrum – will the absence of specific orbital information required result in a dismissal of the application?[125] The FCC appears to have answered this *in practice* when an authorization for MEV-1 was released before the specification of Intelsat-901's orbit,[126] but regulatory clarity is desired.

Another grounds for dismissal looms – if an applicant requests authority to operate in a frequency band that is not allocated "for such operations."[127] Section III above discusses that there is no identified frequency band "for such operations" as ISAM. Until clear guidance is given – or a radiocommunication service is created – this provision of Part 25 creates regulatory risk for ISAM applicants.

Mutually exclusive applications. The Commission will consider applications to be mutually exclusive for reasons of harmful interference "or other practical reason."[128] ISAM operations contemplate co-locating assets, building structures, and performing other operations that may be "mutually exclusive" to having other spacecraft in the area. The Commission should clarify that ISAM missions at locations where the frequencies already in use do not result in mutual exclusivity.

Blanket licensing. Under Part 25, NGSO operators can apply for authorization of multiple spacecraft at one time.[129] Small spacecraft operators may also seek a single authorization to cover up to ten spacecraft.[130] These provisions will support NGSO ISAM operators, who may seek to deploy fleets of servicers or multiple spacecraft to operate collaboratively (e.g. for assembly).

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[124] 47 C.F.R. § 25.112(a)(1).
[125] *See id.* § 25.114(c)(5)(6).
[126] *See* Space Logistics LLC, *License Grant,* IBFS File No. SAT-LOA-20170224-00021 (Dec. 5, 2017) (bifurcating Space Logistics' operational grant between its deployment and rendezvous phase and its relocation phase, granting the former but deferring the latter until its client satellite, IS-901, received authority for deployment modification); Space Logistics LLC, *License Grant*, IBFS File No. SAT-LOA-20170224-00021 (Jun. 20, 2019) (granting Space Logistics' request to relocate its client, IS-901, as a combined vehicle stack following Intelsat's granted application for modification of its FCC deployment license).
[127] 47 C.F.R. § 25.112(a)(3).
[128] *Id.* § 25.155(a).
[129] *See, e.g., id.* § 25.114(a)(2) (discussing application procedures for "blanket authority for an NGSO constellation").
[130] *Id.* § 25.122(b).

GSO ISAM operators do not enjoy similar freedom. Currently, GSO applicants may only seek to authorize a single satellite at a time.[131] The single space station per application provision will deter growth for ISAM operators that seek to deploy a fleet of servicers or multiple spacecraft to support clients in GSO. The Commission should consider allowing GSO ISAM operators to apply for multiple GSO spacecraft under a single application.

Orbital regime movements. Part 25 currently allows for limited orbital relocations. Orbital repositioning can occur *without* a license modification for GSO stations moving with +/- 0.15° of an orbital location assigned to the same licensee[132] or for NGSO stations temporarily moving within an authorized orbital plane.[133] A modification must be applied for and granted for relocations outside of these very limited bounds.[134]

Some ISAM operations, like manufacturing and assembly, may satisfy the requirements to perform an NGSO modification, not requiring prior authorization if they stay within ten kilometers of their orbital shell.[135] However, for most ISAM orbital changes, existing Part 25 would require – at a minimum – 30 days between application and approval.[136] This nullifies business cases for operators contemplating responsive services; for any ISAM operator, this introduces significant regulatory barriers, legal and technical support costs, and programmatic delays.[137] The Commission should introduce a simple mechanism to facilitate orbital regime movements for ISAM operators.

Orbital debris oversight of OTVs. There is a regulatory fog surrounding licensing and debris mitigation oversight authority for "last-mile" service providers. OTVs are initially a primary launch system's payload. Upon deployment from the launch vehicle, OTVs themselves transition from payload to a sort of kick stage, ferrying ridesharing spacecraft integrated with the OTV to their final orbits for deployment. Some OTVs may remain in orbit and continue to host a satellite "payload."

The FCC's understanding of its jurisdiction over application requirements for OTVs must be clarified. Last-mile service providers authorized to date have applied for FCC authorization yet have been granted waivers to space station licensing, indicating these applicants are viewed as more like a "launch

[131] *See, e.g., id.* § 25.114(a)(1) ("…application filed …for *a* GSO space station…") (emphasis added).
[132] *See id.* § 25.118(e).
[133] *See id.*§ 25.118(f).
[134] *See id.*§ 25.117(a), (d); *see also id.* § 25.114(c)(5), (6) (information on orbital parameters required for applications).
[135] *Id.* § 25.118(f)(5).
[136] *Id.* § 25.117(d)(2)(iii) (modifications for GSO orbital locations will be placed in a queue); *Id.* § 25.158(b)(2)(ii) (applications on placed on public notice); *Id.* § 25.151 (a)(3) (noting public notices will be released for receipt of applications for major modifications); *Id.* § 25.151(d) (no application placed on public notice will grant until the expiration of 30 days).
[137] *See, e.g., id.* § 1.1107, Table 1 (2022) (the current cost of a space station modification is $2,495).

system" than a space station.[138] Because launch systems fall under the regulatory purview of the Federal Aviation Administration (FAA), these last-mile service providers would logically apply for and receive operational licenses from the FAA.[139] More recently, the FCC has recently encouraged OTV operators to apply for *full* Part 25 authorizations, seemingly backtracking on the previous rationale. The division of jurisdiction between the FAA and FCC over OTVs is far from clear and must be clarified.

There is an additional issue that must be considered when clarifying jurisdictional oversight. Since the FAA performs an orbital debris assessment for *the launch vehicle*,[140] an OTV operator would not be required to submit one for on-orbit operations, as it is a payload on the launch vehicle. Couple this with an FCC statement that does not review orbital debris assessment reports (ODARs) of a space station's launch vehicle "even if it is submitted,"[141] and it becomes questionable whether proper orbital debris mitigation assessments of OTVs are being undertaken and by whom.[142] The FCC and FAA must work together to clarify oversight of OTVs for orbital debris mitigation.

Regulatory fees. There is a lack of clarity on the fees that the Commissions would assess an ISAM application.[143] The only GSO servicing missions to date, licensed as GSO operations, have not been subject to annual fees.[144] In theory, ISAM missions like OTVs could be assessed the *full* NGSO annual fee – currently $340,005 – for single spacecraft missions.[145] Such treatment for ISAM missions would be grossly inequitable and places the risk of potentially significant costs on the ISAM operator.[146] Following the

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[138] *Compare* Momentus Space, LLC, *License Grant*, IBFS File No. SAT-STA-20211216–00195, at para. 3 (granted April 28, 2022), *with* Spaceflight, LLC, *License Grant*, IBFS File No. SAT-STA-20210205-00017 at para. 2 (granted May 28, 2021), and Spaceflight, LLC, *License Grant*, IBFS File No. SAT-STA-20180523-00042 at para. 2 (granted Oct. 12, 2018), and Spaceflight, LLC, *License Grant*, IBFS File No. SAT-SAT-20150821-00060 at para. 3 (granted Oct. 26, 2016).

[139] *See Amendment of the Commission's Space Station Licensing Rules and Policies,* Report and Order, 18 FCC Rcd. 10760, 68 Fed. Reg. 59127 at ¶ 105 (May 19, 2003) ("[M]atters addressed under the Commercial Space Launch Act and its implementing regulations are most appropriately addressed by the FAA").

[140] *See* 14 C.F.R. § 450.121 (debris analysis required for "vehicle flight").

[141] *Amendment of the Commission's Space Station Licensing Rules and Policies*, *surpa* note 138, para. 105.

[142] *See Mitigation of Orbital Debris*, Second Report and Order, 19 FCC Rcd 11567, 11611, para. 105 (2004) (stating that the FCC does not require, *and has never reviewed*, debris mitigation plans for launch vehicles, "even if it is submitted); *but see* Grant of Application of Momentus Space, LLC, *supra*, at para. 3 (stating "we have reviewed the... orbital debris mitigation plan submitted by Momentus"), and FCC Grant of Application of Spaceflight, IBFS File No. SAT-STA-20210205-00017 at para. 2 (filed May 28, 2021) (stating "we have reviewed the... orbital debris mitigation plan submitted by Spaceflight"), and FCC Grant of Application of Spaceflight, IBFS File No. SAT-SAT-20180523-00042 at para. 2 (filed Oct. 12, 2018) (stating "we have reviewed the... orbital debris mitigation plan submitted by Spaceflight"), and FCC Grant of Application of Spaceflight, IBFS File No. SAT-SAT-20150821-00060 at para. 3 (filed Oct. 26, 2016) (stating "we have reviewed the... orbital debris mitigation plan submitted by Spaceflight").

[143] *See* Reply Comments of Astroscale, MD Docket No. 22-223 (July 18, 2022).

[144] Assessment and Collection of Regulatory Fees for Fiscal Year 2022, *Report & Order,* MD Docket No. 22-223 & 22-301 at Appendix F (Sept. 2, 2022) (listing Satellite Charts for FY 2022 Regulatory Fees, continuing to not include Space Logistics as a licensee, even though Space Logistics holds 2 GSO licenses for operations of MEV 1 and 2).

[145] *See* Reply Comments of Spaceflight, MD Docket No. 22-223, at 2-3 (July 18, 2022).

[146] *Id.* at 3-4.

informational foundation in this docket and considering the number of completed or processing Part 25 authorizations for ISAM missions, establishing a fee category for ISAM missions must be contemplated.[147]

There are many regulatory hurdles facing ISAM operators seeking authorization for the future space infrastructure under Part 25. Additional challenges raised by required orbital debris mitigation showings as applied to ISAM will be explored in the following subsection.

iii. Conclusion: Needed Modifications of Part 25.

Astroscale urges the Commission to transpose the information gathered in this NOI into a subsequent Notice for Proposed Rulemaking. There is already an understanding of how Part 25 creates regulatory barriers or burdens for ISAM operators; these can dissuade, discourage, and delay ISAM companies from establishing themselves or licensing in the United States.

An NPRM, and subsequent regulations, should address the following:

- Clarify which orbital regime ISAM missions should seek authorizations for their mission type and enable ISAM operators to move between orbits in a responsive and coordinated manner.
- Modify regulations addressing dismissal of applications and mutual exclusivity to ensure ISAM-inherent mission characteristics do not trip these regulatory provisions.
- Allow GSO applications for multiple spacecraft.
- Clarify the bounds of Commission oversight of ISAM operations, such as debris mitigation for OTVs.
- Create an annual regulatory fee category for ISAM missions with an appropriately-scoped yearly fee.

Regulatory clarity acts as a lighthouse to industry, and an NPRM to establish rules for ISAM would be a needed and welcome beacon to those facing the uneven shores of Part 25 as it stands today.

B. Building Orbital Debris Mitigation Showings to Incorporate ISAM Missions.

Commercial ISAM missions are novel in the space-based infrastructure they will enable and create. One thing regulators must remain aware of is the risk posed to the orbital debris environment and ensuring operators have plans to mitigate the potential creation of orbital debris. In 2004, the Commission adopted its first order requiring Part 25 operators to file orbital debris mitigation showings,[148] and the regime continues to evolve today.[149]

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[147] *See* Assessment and Collection of Regulatory Fees for Fiscal Year 2022, *supra* note 143, at ¶ 45 ("As we gain more experience in oversight and regulation of this industry, we will better understand how to recover any regulatory costs and benefits that might be associated with these operations.").

[148] *See* Mitigation of Orbital Debris, Second Report and Order, IB Docket No. 02-54 (released June 21, 2004).

[149] *See, e.g.,* Space Innovation & Mitigation of Orbital Debris in the New Space Age, IB Docket Nos. 22-271 & 18-313 (Sept. 30, 2022).

The FCC should keep two key things in mind when contemplating orbital debris mitigation requirements for ISAM missions.[150] The first is that while the commercial operation of these missions and ISAM-devoted spacecraft are relatively new, the underlying technology is not. Both historical procedures and existing applicable standards can guide the Commission in evaluating wholly or partially unknown risks. Second, the Commission should create performance-based regulations to promote growth and allow operators flexibility and inventiveness in satisfying regulations. The institutional risk knowledge related to ISAM, forthcoming and published standards, and the rationale for creating performance-based regulations will all be explored further below.

i. Resources to Guide Creation of ISAM Orbital Debris Mitigation Requirements Currently Exist.

ISAM is not a new phenomenon; safe practices have been developed over decades, from the Apollo program to Hubble's servicing missions to the building of the International Space Station and docking supplies and personnel. However, until recently, it was largely governments (and in particular, the United States) that conducted these sorts of missions, not commercial entities. Thankfully, many of the lessons learned in ISAM safety by government expertise are being shared with the emergence of a growing ISAM industry. In 2018, a Satellite Servicing Safety Framework was provided by subject matter experts in RPO, robotics, and on-orbit servicing from government organizations, including DARPA and NASA, to the CONFERS members[151]. It lays out satellite design and mission assurance considerations, satellite servicing operations safety, and a servicing mission safety package.

CONFERS Recommended Design and Operational Practices.[152] Published in 2021, this industry-led consensus document is a primary source for risk and mitigation considerations for ISAM operations. The first consideration is to design servicing vehicles to account for layered risk mitigation and operational safety across hardware, software, ground segment, and mission operations. Mission operations in particular should use passively safe orbits, safety zones, and keep-out spheres for maneuver planning. Experimental or high-risk vehicles should perform initial check-out at altitudes that minimize the consequences of mishaps in internationally recognized protected zones. Members are encouraged to use proven procedures,

[150] ISAM NOI, *supra* note 1, at ¶ 28 ("In general, are there updates to the Commission's orbital debris mitigation rules that would help to address such risks, through modified disclosure requirements, for example, that would facilitate Commission consideration of whether grant of a license would service the public interest? If so, what would be the relevant changes to the Commission's rule to cove the additional risks, if any, presented by such activities?").
[151] See CONFERS Satellite Servicing Safety Framework: Technical and Operational Guidance Document, CONSORTIUM EXECUTION RENDEZVOUS & SERV. OPERATIONS (draft, Apr. 2018) https://www.satelliteconfers.org/wp-content/uploads/2018/07/2018-04-05CONFERSSatelliteServicingSafetyFramework.docx.
[152] *See* CONFERS Recommended Design and Operational Practices, *supra* note 43.

have trained and qualified operators, and keep security in mind across all phases of service activities. Transparency is of paramount importance to CONFERS members to mitigate the potential for future debris. It is one of the very limited number of industry groups to encourage sharing of anomaly resolution and share best practices based on anomaly attribution processes to the extent possible. In these published recommendations, CONFERS also refers to internationally recognized guidelines and standards developed by the United Nations Committee on the Peaceful Uses of Outer Space (UN COPUOS), the Consultative Committee for Space Data Systems (CCSDS), the International Organization for Standardization (ISO) standard ISO 24113, and guidelines published by the Inter-Agency Space Debris Coordination Committee (IADC). CONFERS members have built-in spaceflight safety and sustainability into their ethos.

ISO 24113:2019 Space Systems — Space Debris Mitigation Requirements.[153] ISO Standard 24113 defines requirements for space debris mitigation of any object launched into Earth's orbit, from launch vehicle stages to operating spacecraft, including objects released as part of normal operations. These requirements aim to reduce the growth of space debris by ensuring objects entering space are designed, operated, and disposed of in a way that prevents generating debris. This is an example of a standard that can be applied to new space operations, regardless of the new activity – be it refueling, assembly, or manufacturing.[154]

This is not the only space debris mitigation standard ISO has published. ISO has also released the following:

- ISO/TR 18146:2020 Space systems — Space debris mitigation design and operation manual for spacecraft[155]
- ISO/TR 20590:2021 Space systems — Space debris mitigation design and operation manual for launch vehicle orbital stages[156]
- ISO 20893:2021 Space systems — Detailed space debris mitigation requirements for launch vehicle orbital stages[157]
- ISO 23312:2022 Space systems — Detailed space debris mitigation requirements for spacecraft[158]

[153] *See* Int'l Std. Org., ISO 24113:2019, *Space systems – Space debris mitigation requirements* (July 2019), https://www.iso.org/standard/72383.html.
[154] *See* ISAM NOI, *supra* note 1, at ¶ 28 (asking "Are there additional risks of debris generation implication in such [in-space refueling] operations, and if so, what steps can be taken to mitigate such risks?" and related questions around assembly and manufacturing).
[155] *See* Int'l Std. Org, ISO/TR 18146:2020, *Space systems — Space debris mitigation design and operation manual for spacecraft* (Oct. 2020), https://www.iso.org/standard/77688.html.
[156] *See* Int'l Std. Org, ISO/TR 20590:2021, *Space systems — Space debris mitigation design and operation manual for launch vehicle orbital stages* (Apr. 2019), https://www.iso.org/standard/81216.html
[157] *See* Int'l Std. Org, ISO 20893:2021, *Space systems – Detailed space debris mitigation requirements for launch vehicle orbital stages* (Feb. 2021), https://www.iso.org/standard/73023.html.
[158] *See* Int'l Std. Org, ISO 23312:2022, *Space systems – Detailed space debris mitigation requirements for spacecraft* (July 2022), https://www.iso.org/standard/75221.html.

- ISO 24330:2022 Space systems – Rendezvous and proximity operations (RPO) and on orbit servicing (OOS) – Programmatic principles and practices[159]

NASA Procedural Requirement 8715.6B – Limiting Orbital Debris and Evaluating the Meteoroid and Orbital Debris Environments.[160] NASA in 2017 published a standard to reflect NASA's policy to limit orbital debris generation and disclose the responsibility within NASA organizations. Additionally, Process for Limiting Orbital Debris – NASA-STD-8719.14 is an expansion on NPR 8715.6, providing specific technical requirements for limiting orbital debris and methods. The Handbook for Limiting Orbital Debris – NASA-HDBK-8719.14 serves as the foundation for NPR 8715.6 and NASA-STD-8719.14, providing background and reference materials for the requirements and technical standards.

ii. Orbital Debris Showings Should be Crafted as Performance-Based Regulations.

The Commission can best encourage ISAM technologies by crafting performance-based regulations.[161] Performance-based regulations specify an organization's outcome but leave the means of compliance to the organization's discretion.[162] 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 particular technologies obsolete and can reduce U.S. ISAM providers' competitiveness in the global market.

Performance-based regulations have gained popularity worldwide and have been advocated in the halls of the U.S. government since the 90s.[163] In 1993, Executive Order No. 12866 directed federal agencies to develop performance-based standards to achieve a more efficient regulatory scheme.[164] Consecutive administrations have continued to encourage a move towards performance-based regulations.[165] In 2020,

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[159] Int'l Std. Org, ISO 24330:2022, *Space systems – Rendezvous and proximity operations (RPO) and on orbit servicing (OOS) – programmatic principles and practices* (July 2022), https://www.iso.org/standard/78463.html.
[160] *See* NPR 8715.6B, *NASA Procedural Requirements for Limiting Orbital Debris and Evaluating the Meteoroid and Orbital Debris Environments*, NASA (Feb. 16, 2017), https://nodis3.gsfc.nasa.gov/displayDir.cfm?t=NPR&c=8715&s=6B.
[161] *See* ISAM NOI, *supra* note 1, at ¶ 39 ("We also seek comment on ways to facilitate development of and competition in ISAM activities[…] Are there any regulatory barriers that may increase cost or prevent entry that can be removed or modernized to facilitate innovation and investment in ISAM in the public interest?).
[162] Cary Coglianese et al., *Performance-based Regulation: Prospects and Limitations in Health, Safety, and Environmental Protection*, 55 ADMIN. L. REV. 705 (2003).
[163] Id. at 707 (noting that performance-based regulations have received increasing attention); *see also* Cary Coglianese, *The Limits of Performance-based Regulation*, 50 U. MICH. J. L. REFORM 525, 527 (2017) ("The global trading regime operating under the World Trade Organization formally favors the use of performance standards,").
[164] Executive Order 12866, *Regulatory Planning and Review*, 58 Fed. Reg. 51735 (Sept. 30, 1993).
[165] Cary Coglianese et al., *supra* note 161, at 707.

the Federal Aviation Administration updated all launch and re-entry regulations to a performance-based standard.[166]

The Office of Management and Budget (OMB), in their 1998 Circular, defines a performance-based standard (a synonym for performance-based regulation) as "a standard … that states requirements in terms of required results with criteria for verifying compliance but without stating the methods for achieving required results. A performance standard may define the functional requirements for the item, operational requirements, and/or interface and interchangeability characteristics."[167]

A performance-based regulation has three essential parts: the requirement, the criterion, and the test.[168] The requirement is the performance being mandated, criteria are the quantitative metrics attached to the intent of the requirement, and the test is how the entity is being measured.[169] The following is an example regulation that combines all three components: "Vegetation must be controlled so that it remains at least three feet away from the railroad track." The requirement is vegetation control, the criteria is a three-foot distance from the track, and the test is a tape measure.[170]

The requirement, criterion, and test of a performance-based regulation must also be considered in terms of specificity. Performance-based regulation can be loosely or tightly specified.[171] As one author frequently heard in the halls of the Federal Aviation Administration, the purest performance standard is, "Be safe." Clearly, there is more to crafting an acceptable performance standard than such a vague direction."[172] A performance standard that only says "be safe" would give the regulated party a requirement but no criteria for what is 'safe' and no test of how safety will be measured. A loosely specified standard will "call for regulators to make qualitative judgments," while a tightly defined standard employs quantitative performance measures.[173] All three components must be present for a performance-based regulation to function with and without ambiguity (requirement, criterion, and test). In other words, the regulation must be tightly specified.

Instituting an aggregate probability of collision metric is one example of a performance-based orbital debris mitigation regulation that the Commission could and should adopt. The requirement is that an operator aggregate collision risk across spacecraft under a single authorization. The criterion would be the aggregate collision risk threshold. The test would be showings before deployment and periodic

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[166] *Legislation & Policies, Regulations & Guidance,* FAA (Oct. 25, 2022), https://www.faa.gov/space/legislation_regulation_guidance.
[167] Office of Mgmt. & Budget, Exec. Office of the President, OMB Circular A-119 3(B)(c) (Feb. 10, 1998).
[168] David Hemenway, Performance vs. Design Standards 1 (U.S. Dep't of Commerce, NBS/GCR 80-287, 1980).
[169] *Id.*
[170] Cary Coglianese et al, *supra* note 164, at 710.
[171] *Id.* at 709.
[172] Montgomery et al., *Performance Standards vs. Design Standards: Facilitating a Shift Toward Best Practices* 4 (Mercatus Working Paper, Mercatus Ctr. at George Mason Univ., 2019).
[173] Coglianese et al., *supra* note 164, at 710.

disclosures during operation to ensure the constellation complied with anticipated showings.[174] The regulation would free operators to satisfy the requirement with their own innovations, which still protects the space environment.

The Commission should craft any updates to orbital debris mitigation regulations for ISAM operations, or generally, to be performance-based.[175] By defining a clear requirement, criterion, and test, the orbital debris environment can be protected while leaving ISAM operators flexibility to determine how they will achieve the requirement. The fact that performance-based regulations are technology-neutral means they will also serve to bound new missions – such as refueling – without operators and regulators needing to wait potentially years for prescriptive regulations to develop.

C. Space-based Interactions: Accommodating Servicing, Determining Authority Burdens, and Documenting Consent.

The FCC poses several questions related to space station authorization for both a client and servicer, international considerations, and the Commission's appropriate regulatory role.[176] This subsection will address the correct party on which to place an authorization burden, the Commission's role in servicing licensing, and documentation of consent for servicing operations.

i. Who's Authorization Is It Anyway?

The Commission inquires who, in servicing missions, should carry the burden of obtaining communication authorizations.[177] The authorization burden for a servicing operation should be split between a servicer and a client entity respectively. This is current FCC practice and can be seen in a historical example.

In Space Logistics's application for MEV-1, they informed the FCC that SpaceLogistics had already contracted with Intelsat to provide life extension services for one of Intelsat's satellites.[178] On December 5, 2017, the FCC granted Space Logistics the authority to construct, deploy and conduct TT&C operations with MEV-1 as the spacecraft performed initial operations *and* rendezvous, proximity operations, and docking ("RPOD") with IS-901 in the graveyard orbit.[179] Nowhere in the license grant did the FCC authorize the "servicing" of the two spacecraft.[180] In fact, the FCC initially deferred part of Space

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[174] *See* Reply Comments of Astroscale, IB Docket No. 18-313 at 2-5 (Nov. 10, 2020).
[175] ISAM NOI, *supra* note 1, at ¶ 28 ("In general, are there updates to the Commission's orbital debris mitigation rules that would help to address such risks, through modified disclosure requirements, for example, that would facilitate Commission consideration of whether grant of a license would serve the public interest?").
[176] *Id.* at ¶¶ 23, 25-26.
[177] *Id.* at ¶ 23.
[178] Space Logistics, Narrative, File No. SAT-LOA-20170224-00021 (filed Feb. 24, 2017).
[179] *See* Grant, Space Logistics, Application, File No. SAT-LOA-20170224-00021 (granted Dec. 5, 2017).
[180] *See id.*

Logistics' MEV-1 application until Intelsat modified IS-901's authorization to operate in a new orbit.[181] This piecemeal authorization process demonstrates that the FCC views a client's and servicer's operational authority separately rather than a holistic mission authorization grant. The same story plays out for MEV-2.[182]

The split burden between servicers and clients is the most logical arrangement for approving servicing operations between two operators. An operator can decide under the existing regime who would need to apply for Commission approval based on the operational parameters of the mission and the reflected ground station requirements.

A split burden will also future-proof the licensing and oversight of space operations to align with the Commission's current "facilities-based" approach[183] as the physical design approaches for space systems grow increasingly modular. Unlike non-modular or 'unprepared' systems, which do not engage in planning for in-space servicing, prepared systems harness interoperable interfaces for power, data, thermal, mechanical, and fluid connections and transfer between space objects. It is conceivable that a spacecraft, at some point, will exchange communications hardware without altering anything else; for example, an operator could choose to upgrade to software-defined radios while the asset is still in space.[184] The Commission should plan for a "facilities-based" approach of the future, where a discrete component with a communication device is the subject of licensing.[185]

ii. Authorizations for Servicing Should Not Exceed the Scope of Current FCC Practice.

The Commission inquiries about the appropriate scope of authorizations for a servicer or client, noting the rationale of both radiofrequency variance and "simply to address the additional scope of

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[181] *Id.*
[182] Space Logistics, Narrative, File No. SAT−LOA−20191210−00144 (filed Dec. 10, 2019); Grant, Space Logistics, Application, File No. SAT−LOA−20191210−00144 (granted March 25, 2020).
[183] ISAM NOI, *supra* note 1, at ¶ 16 ("The Commission's licensing for space stations is "facilities-based," meaning that the license is associated with a specific radio station.").
[184] *See* Deborah Tomek et al., *The Space Superhighway: Space Infrastructure for the 21st Century*, IAC 2022 at 1 (Oct. 2022) ("For example, science and human missions will require spacecraft larger than any foreseeable launch vehicle fairing, defense missions will require persistent assets that are upgradable and resilient, and commercial space missions will require cost-effective ways to update to the latest technology on orbit…The opportunity to replace or upgrade instruments, subsystems, and technologies at an increased cadence would inspire and accelerate innovation by providing the means to demonstrate new sensor technology and ensure state-of-the-art observation.").
[185] The one tweak that should be made to the Commission's understanding of a "facility" is the requirement of power. *See* ISAM NOI, *supra* note 1, at ¶ 16 ("That station includes "accessory equipment" necessary to conduct communications activities at a location."). Requiring a "facility" – a discrete space-based unit with all components necessary to conduct communications *excluding* an interface to power – to obtain a license solves both the approach to spacecraft "hosted payloads" on OTVs and will allow the Commission to ensure a new communications device is authorized before being plugged into existing infrastructure. This also allows infrastructure providers who wish to provide platforms a level of business separation from potential hosted clients, who would be required to obtain their own authorization.

activating involving servicing."[186] The FCC's statutory authority over spacecraft is limited to licensing the use of radio spectrum and encouraging its use in the public interest,[187] not the actual operations of a spacecraft.[188] Even the Executive Branch recognizes this gap in government authority.[189] Accordingly, the FCC's appropriate role in overseeing servicing activities is *regulating communications*.

ISAM operations and the fact pattern of collocating two or more international spacecraft is a familiar scenario for the FCC. The Commission currently considers proximity operations of spacecraft when it authorizes GSO space stations.[190] The same can and should occur for ISAM missions. Any further questions of consent from an operator or foreign administration can be addressed through simple documentation requirements and filings into an authorization application.[191] A similar standard of only requiring documented consent before an operator performs an operation upon another spacecraft can also be seen in remote sensing authorizations.[192]

In summary, for ISAM mission operations with U.S.-licensed spacecraft,[193] it is appropriate for the Commission to authorize any changes to radiocommunications and require documentation of consent to collocate or otherwise involve two space assets. The FCC is concerned with the efficient use of a limited resource for the public benefit. Any questions that approach "authorization" or "continuing supervision" for the FCC to license servicing missions are beyond the scope of the authority delegated to the FCC and beyond concerns about spectrum use. The FCC should limit any international showings or documents required to those currently required for similar co-location scenarios between international assets.

D. Solutions and Conclusions – Crafting a Licensing Regime to Incorporate ISAM.

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186 ISAM NOI, *supra* note 1, at ¶ 23.

187 *See Hearings on Communications Satellites Before the House Committee on Interstate and Foreign Commerce*, 87th Cong., 1st Sess., pt. 1, at 86 (1961) (testimony of Newton Minow, then FCC Chairman), https://www.govinfo.gov/content/pkg/CHRG-87hhrg80559Op1/pdf/CHRG-87hhrg80559Op1.pdf (last visited Oct. 26, 2022); *In the Matter of the Establishment of Domestic Noncommon Carrier Commc'n Satellite Facilities by Nongovernmental Entities*, 2 F.C.C.2d 668 (1966); 47 U.S.C. § 309(a).

188 *See*, Danielle Miller, Elsbeth Magilton, *On-Orbit Satellite Servicing Standards Are A Necessity for the Private Space Industry*, Air & Space Law., 2018, at 4 ("Although every satellite in space uses spectrum and thus to some extent is subject to FCC regulation, the U.S. government's lack of regulation of actual satellite operations following launch and before reentry is a glaring omission.").

189 *See* Letter from John P. Holdren, Dir. & Assistant to the President for Sci. & Tech., to Sen. John Thune & Rep. Lamar Smith (Apr. 4, 2016), https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/csla_report_4-4-16_final.pdf (identifying on-orbit activities as an emerging area with unclear oversight); Jeff Foust, *New Policy Directive Implements Commercial Space Regulatory Reforms*, SPACE NEWS (May 24, 2018), https://spacenews.com/new-policy-directive-implements-commercial-space-regulatory-reforms/.

190 *See, e.g.*, 47 C.F.R. 25.140(a)(2) (discussing notifications required if a GSO FSS station is less than two degrees from a co-frequency GSO).

191 For example, the Government of Bermuda at one time filed a letter in support of grant of a space station authorization into an open application for a U.S. operator that was processing before the FCC. *See* EchoStar Satellite Operating Company, Order and Authorization, File No. SAT-STA-20130220-00023 ¶ 5 (released April 1, 2013)

192 15 C.F.R. § 960.9(b) (2022).

193 Both U.S. and market access licensees.

In summary, there are four primary conclusions in relation to licensing process and ISAM missions overall that Astroscale asserts.

- Part 5 should remain an available route for ISAM operators to license experimental missions, with non-experimental operations to be licensed under Part 25.
- Part 25 poses significant barriers to ISAM applicants. These include problems in identifying what orbital regime to license in, unclear application of regulations related to dismissal and mutually exclusive applications, inability to license multiple GSO servicers at one time, significant costs and delays before orbital movements could be conducted, and blurred jurisdictional treatment of OTVs. It will not be enough for the Commission to accommodate ISAM operations through non-binding regulatory guidance; investment certainty demands that the FCC promptly open an NPRM to create regulations accounting for ISAM operations.
- History and standards currently exist to support the Commission in understanding the orbital debris risks posed by ISAM technology and operations and ways to mitigate those risks. Updated regulations to account for ISAM operations must be performance-based to allow continued innovation and to future-proof regulations. A well-written performance-based regulation will serve not just the technology that exists today but also the technology of the near future.
- For servicing interactions, the Commission should continue its practice of facilities-based licensing and authorize the client and servicer separately. Documentation of consent for multi-national missions can be accomplished through notification filings into authorizations.

These are not conclusions based on academic research. This discussion is not theoretical for Astroscale. All the provisions mentioned above are genuine questions and considerations facing U.S.-based ISAM startups. Multi-billion dollar companies may have the resources to conquer regulatory regimes and overcome vagueness in support of their operations; emerging industry does not. Now is the time to institute and navigate regulatory reform together.[194]

V. ISAM Mission Support Orbital Debris Remediation.

The creation of space infrastructure is not solely an additive process but also the implementation of mechanisms to remove or remediate debris and other objects cluttering the outer space environment. This section will discuss the economics and technical readiness of remediation technologies before suggesting how the FCC can encourage and integrate remediation technologies into the regulatory regime.

A. Orbital Debris Remediation is a Sustainable Practice With Developing Service Providers.

[194] Similar partnerships between industry and their regulators can be seen at the FAA and NOAA, where maturing industries evolve with and alongside maturing understanding of new regulatory provisions.

The Commission asks about the state-of-the-art in active debris remediation or removal technologies.[195] As a preliminary matter, Astroscale offers clarity on the language used in the following section. The term "remediation" is understood to be "the forced modification of a debris object trajectory by means external to the object, to include removal of an object entirely from space."[196] Remediation is an umbrella that includes *both* ADR and EOL technologies. ADR is here defined as the removal of *unprepared* objects, such as derelict upper stages, small debris objects, or GSO spacecraft not designed with intentional removal interfaces. EOL, alternatively, refers to docking and disposal of *prepared* objects, such as NGSO spacecraft deployed with docking plates already incorporated into the design. While both technologies make up remediation overall, it is essential to understand the distinction between ADR and EOL as used by industry. The two subcategories have vastly different costs, technical readiness levels, and client objects.

i. Current Progress in Remediation: ADR & EOL Technologies.

The Commission asks about the technical readiness, state-of-the-art, and paths of development in ADR and EOL technologies.[197] This section will explore those metrics of both remediation and removal services before turning to how the Commission can continue to promote their growth, innovation, and development.[198]

Active Debris Removal. Debris remediation includes ADR of large, unprepared objects and passive removal of smaller objects.[199] Removal of large, unprepared space objects is becoming a priority given the number of legacy space objects occupying valuable orbits and the risk they pose to the exponentially-increasing satellites in orbit.[200] The variability of debris types, sizes, tumble rates, and docking compatibility necessitates a wide range of approaches for removal efforts.

Several companies are developing novel concepts to meet the scope of demands.[201] These include technologies that employ techniques such as docking, grappling, or the deployment of polymers to trap

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195 ISAM NOI, *supra* note 1, at ¶ 29 ("What is the state of the art of active debris remediation or removal technologies?").
196 ORBITAL DEBRIS RES. & DEV. INTERAGENCY WORKING GRP., NAT'L SCI. & TECH. COUNCIL, NATIONAL ORBITAL DEBRIS RESEARCH AND DEVELOPMENT PLAN at 11 (Jan. 2021) [*hereinafter* National Debris Plan].
197 ISAM NOI, *supra* note 1, at ¶ 29.
198 *Id.*
199 Passive removal methods increase the atmospheric drag exerted on an NGSO object; this can be achieved through mechanisms like drag sails, laser nudging from the ground, etc.
200 *Active Debris Removal,* ESA, https://www.esa.int/Space_Safety/Space_Debris/Active_debris_removal (last visited Oct. 31, 2022).
201 ISAM NOI, *supra* note 1, at ¶ 29 ("What is the current reliability and technical readiness of these [remediation] technologies?").

debris of various sizes.[202] Many operators in this field are early-stage, while associated technologies range from low-TRL concept phases to in-space demonstrations.

There are notable companies leading the commercialization of remediation technologies. Astroscale Japan has the most advanced capability to remove large debris objects from orbit. Astroscale Japan's ADRAS-J spacecraft was selected by the Japan Aerospace Exploration Agency (JAXA) for a Phase I inspection demonstration in 2023, and the Phase II removal of the stage will occur at a later date.[203] Other companies that are considered state-of-the-art and have completed, or are nearing, demonstration phases include RemoveDEBRIS from the University of Surrey[204] and ClearSpace-1 from Swiss startup Clear Space in partnership with the European Space Agency.[205]

Current ADR efforts require bespoke solutions to accomplish their mission objectives, so price variability is expected relative to the service provider and client object. Most initiatives will be government-funded in the near term due to the focus on derelict objects such as upper stages. As the market matures, more robust price estimates for removing different debris types are anticipated.

End-of-Life. In addition to removing unprepared legacy objects, EOL disposal of prepared spacecraft will be a core component of ensuring the stability of Earth's orbital operating environment moving forward. Prepared spacecraft are equipped with standardized interfaces, such as docking plates, which allow them to integrate with a servicer tug that can perform maintenance or move the client to a disposal orbit. Docking plates are intended to be a low-cost, minimally intrusive innovation that can be integrated with spacecraft with no operational degradation issues.[206] The concept is analogous to a standardized tow hitch for cars, enabling satellites to be removed in case of failure or EOL.[207]

EOL capabilities offered by leading providers are at advanced TRLs.[208] In NGSO, the ELSA-d demonstration has paved the way towards multi-mission end-of-life operations. Astroscale U.K. is partnering with OneWeb on a $2.8 million agreement to perform end-of-life services on its satellite

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202 Cavacuiti et al., *supra* note 21.

203 While JAXA has not yet released the entire solicitation for Phase II of the project, Astroscale Japan was selected as a contracting party for the Front-Loading technology Study, a ground test of development hardware and software for Phase II. Astroscale Selects Rocket Lab to Launch Phase I of JAXA's Debris Removal Demonstration Project, Astroscale (Aug. 22, 2022), https://astroscale.com/astroscale-selected-as-contract-partner-for-front-loading-technology-study-in-phase-ii-of-jaxas-commercial-removal-of-debris-demonstration-project/.

204 Airbus' RemoveDEBRIS is a system that deploys harpoons and tethers for debris remediation and was successfully tested from the ISS in 2018. RemoveDEBRIS | Airbus

205 ClearSpace's ClearSpace-1 will rendezvous and capture a defunct Vespa upper stage before burning it up in the atmosphere in 2025. ESA - ESA commissions world's first space debris removal

206 Docking Plate - Astroscale, Securing Space Sustainability

207 Like a Tow-hook for Satellites: Astroscale Launches Docking Plate to Capture Defunct Satellites - Astroscale

208 ISAM NOI, *supra* note 1, at ¶ 29 ("What is the current reliability and technical readiness of these [remediation] technologies?").

constellation in 2024 using Astroscale docking plates.[209] Widespread adoption of standardized docking plates allows spacecraft such as Astroscale's ELSA-M to service multiple spacecraft in a single mission, whether the objective is removal due to premature failure, routine servicing, or end-of-life disposal.[210] Cost estimates are variable for end-of-life services. The ability to service entire fleets of satellites in a single mission will reduce servicing costs in the near term, as will the widespread adoption of standardized interfaces.[211]

To promote continued growth, innovation, and development of ADR technologies, the Commission should support appropriate intragovernmental efforts for large-object remediation and ensure a clear path to licensing for innovative companies seeking to deploy commercial solutions. Moreover, this increased compatibility will further incentivize the interoperability of space systems with the U.S. Government as well as commercial partners and allies. Additionally, performance-based requirements that define EOL results but not necessarily a means of accomplishing them will allow service providers to leverage future technological advancements that have yet to be developed or known. This will promote creative and unique solutions at competitive price points as companies create novel methods for accomplishing end-of-life disposal or active remediation of large space objects.

ii. Remediation of Orbital Debris Provides Economic Return, at Minimum, in EOL Scenarios.

The economic value of an orbital environment free of debris has yet to be quantified. As a result, the most accurate measure of financial returns associated with debris remediation is realized through streamlined operations and the reduction of propellant-consuming collision avoidance maneuvers. Increased predictability fosters a more secure operating environment, much like it is safer and less costly to operate on roadways free of car parts. For example, large debris objects, such as defunct upper stages, are considered the most dangerous articles of debris due to their ability to promulgate additional fragments through collisions, explosions, and breakups.[212] NASA projects that LEO's debris growth can stabilize if

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[209] Astroscale U.K. first demonstrated EOL services in 2021 with the launch and operation of ELSA-d. The commercial line of EOL servicers – ELSA-M – are in production and the first operation to deorbit a client is expected to occur at the end of 2024. https://astroscale.com/elsa-m/; https://astroscale.com/astroscales-elsa-d-mission-successfully-completes-complex-rendezvous-operation/; Astroscale UK Signs £2.5 Million Agreement to Develop Space Debris Removal Technology Innovations with OneWeb - Astroscale

[210] Astroscale UK Signs £2.5 Million Agreement to Develop Space Debris Removal Technology Innovations with OneWeb - Astroscale

[211] ISAM NOI, *supra* note 1, at ¶ 31 ("Are there generic technical requirements that could facilitate active debris removal…?").

[212] Upper stages top list of most dangerous space debris - SpaceNews

five such objects are removed from orbit annually.[213] Doing so would reduce the number of costly collision avoidance maneuvers that may or may not be necessary due to the current paucity of debris-related data.

Without an established market for debris remediation, satellite service providers are already incurring higher operating costs due to the risk of debris. It is estimated that five to ten percent of total mission costs – hundreds of millions of dollars in some cases -- are related to protective and debris mitigation measures for assets in GSO.[214] Other debris-related costs can result from damage from impact, preventative shielding, or conjunction warnings that could be false or inaccurate due to insufficient data on orbital congestion.[215] The long-term costs of *failing* to remediate Earth's orbital debris population are staggering, including diminished access to valuable Earth science and climate data, communication services, and economic prospects in cislunar space.[216]

Requiring EOL interfaces is a crucial area where economic return can be realized quickly, and the technical requirements are largely generic across the industry.[217] Docking plates that would enable EOL service can be as small as fifteen centimeters in diameter and only a few hundred grams in mass. Docking plates are also designed to have minimal or no impact on the client spacecraft attitude, thermal, communication, and other control systems, are completely passive, and can outlast the client functionality for decades in space.[218] Standardizing docking interfaces will reduce client risk by assuring that the interface would be compatible with an ever-growing range of servicing companies that support EOL and lower costs due to the competitive pricing offered by service providers. Overall, adopting EOL interfaces requires minimal investments, both fiscally and in terms of spacecraft hardware budget, but ensures significant returns through enabling removal.

iii. The Commission Should Enable Remediation Through Regulation.

The FCC should allow operators to include remediation and removal technologies as part of orbital debris mitigation reviews.[219] As these technologies are in various stages of development, Astroscale

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[213] Final Report - IG-21-011 - NASA's Efforts to Mitigate the Risks Posed by Orbital Debris (oversight.gov)
[214] The Economics of Space Debris in Perspective | ESA Proceedings Database
[215] *Id.*
[216] *Id.*
[217] ISAM NOI, *supra* note 1, at ¶ 31 ("What industry adaptations could facilitate active debris removal with consideration to return on investment (e.g., fuel costs, weight, import costs, procurement)? Are there generic technical requirements that could facilitate active debris removal across the industry…?").
[218] Technologies – Altius Space Machines (altius-space.com); Docking Plate - Astroscale, Securing Space Sustainability
[219] ISAM NOI, *supra* note 1, at ¶ 30 ("We seek comment on whether and how the Commission should consider active debris removal as part of an operator's orbital debris strategy.").

supports the Commission analyzing reliance on post-mission disposal or backup post-mission disposal on a case-by-case basis.[220]

B. ISAM Missions Are Complementary to Upholding Current Orbital Debris Requirements.

The Commission asks how they can promote innovation and investment in ISAM without simultaneously reducing incentives for compliance with rules for orbital debris mitigation.[221] Astroscale submits that ISAM investment and compliance with orbital debris mitigation rules are complementary actions.

USG orbital debris mitigation practices highlight the complementary nature of requirements and technological advancement. The 2019 update to the U.S. Government Orbital Debris Mitigation Standard Practices advised that "when practical, operators should consider the benefits of going beyond the standard practices and take additional steps to limit the generation of debris," citing itself as a parallel contribution to safe space operations and the sustainability of space activities.[222] Additionally, Objective 4, *Postmission Disposal of Space Structures*, states that "[p]rograms and projects will plan for disposal procedures for a structure … at the end of mission life to minimize impact on future space operations." One of the six compliance methods is direct retrieval, wherein an operator "[r]etrieve[s] the structure and remove[s] it from orbit preferably at completion of mission, but no more than 5 years after completion of mission,…".[223] Direct retrieval is an in-space operation enabled solely by applying crewed and robotic ISAM capabilities. Ultimately, the U.S. Government both heightened orbital debris mitigation requirements and supported the ISAM mission simultaneously; the two complement one another.

For missions that encounter anomalies, failures, and other mishaps, especially as they approach the end of their design lifetimes, the use of ISAM service providers for direct retrieval and disposal at end of life is often the only means of facilitating compliant disposal at all.[224] The Commission can simultaneously promote innovation and investment in ISAM *and* improve compliance with orbital debris mitigation regulations.

VI. ISAM and Navigating Intragovernmental and Intergovernmental Relationships.

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[220] ISAM NOI, *supra* note 1, at fn. 55.
[221] ISAM NOI, *supra* note 1, at ¶ 39.
[222] *See* U.S. Government Orbital Debris Mitigation Standard Practices, 2019 Update, NASA Johnson Space Center Orbital Debris Program Office, at 1. https://orbitaldebris.jsc.nasa.gov/library/usg_orbital_debris_mitigation_standard_practices_november_2019.pdf
[223] *Id.*, at 6.
[224] *See* 5 year rule.

The Commission asks several questions about intragovernmental and intergovernmental relationships that would facilitate ISAM missions. To reiterate a prior statement - any questions that approach "authorization" or "continuing supervision" for the FCC to license servicing missions are beyond the scope of the authority delegated to the FCC and beyond concerns about spectrum use.[225] The FCC should allow the appropriate channels for these discussions to develop considerations of mission authorization[226] and remain in lockstep with the intragovernmental process as it develops.

The Commission should also engage the interagency to consider the application of capped or tiered liability indemnification structures for ISAM operations and the utility and benefit of new insurance requirements or other performance-based incentives for 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.

Internationally, under the scope of the U.S. government's obligations under the United Nations treaty system, the Commission should work with the interagency and Congress to clarify liability, insurance, and indemnification requirements for ISAM missions for commercial license applicants and market access applicants. As discussed above, international interactions should also include advocacy before the ITU and during the WRC23 process to secure spectrum access for ISAM missions.

VII. Conclusion

The Commission seeks comment on regulatory barriers that increase costs or prevent entry that can be removed or modernized to facilitate innovation, competition, and investment in a diversified ecosystem of ISAM service providers and solution options. 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. 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. Astroscale urges the Commission to promptly open a Notice of Proposed Rulemaking and take regulatory action to facilitate ISAM operations and U.S. leadership.

[225] Astroscale is additionally puzzled by the Commission's inquiries around planetary protection. *See* ISAM NOI, *supra* note 1, at ¶¶ 34-36. The 2020 National Space Policy calls for development of these guidelines by the Director of the Office of Science and Technology Policy, in coordination with NASA, Commerce, and other agencies as appropriate. Astroscale advises the FCC to align with the National Space Policy and develop policies with the rest of the U.S.G., rather than raise the issue separately within this NOI.

[226] National Space Council, *Notice of In-space Authorization and Supervision Policy Listening Sessions*, Request for Comments, 87 Fed. Reg. 62845 (Oct. 17, 2022).

Astroscale thanks the Commission for their consideration and the opportunity to expand the record on important matters related to the ISAM missions and the future of space infrastructure.

Respectfully submitted,

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