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Space Traffic Management: Time for Action

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INTRODUCTION

Outer space has long been characterized as "contested, congested, and competitive."[1] More than four thousand eight hundred active satellites currently orbit Earth, representing over forty nations,[2] and nearly twenty-five thousand satellites are projected to join by 2030.[3] Moreover, spacefaring entities are testing the limits of space exploration: Visionary space companies are aiming to launch space tourism programs and send humans to space within the decade, and governments and militaries are increasing activity in cislunar space—the sphere formed by the Earth-Moon radius—to leverage advantageous orbital regions. As humanity expands its frontiers deeper into the galaxy, the threats to US and allied space capabilities will continue to increase.[4] Yet, despite the proliferation of space activity, the ability of international and national bodies to track and regulate space objects—often referred to as space traffic management (STM)—reflects a past era wherein few actors conducted limited operations in space.

1 Office of the Director of National Intelligence, *National Security Space Strategy: Unclassified Summary*, January 2011, 1, https://www.dni.gov/files/documents/Newsroom/Reports%20and%20Pubs/2011_nationalsecurityspacestrategy.pdf.

2 Anna Wainscott-Sargent, "Peeling Back the Onion of Space Crowding: Myths vs. Reality," Via Satellite, June 27, 2022, https://interactive.satellitetoday.com/via/july-2022/peeling-back-the-onion-on-space-crowding-myths-vs-reality/.

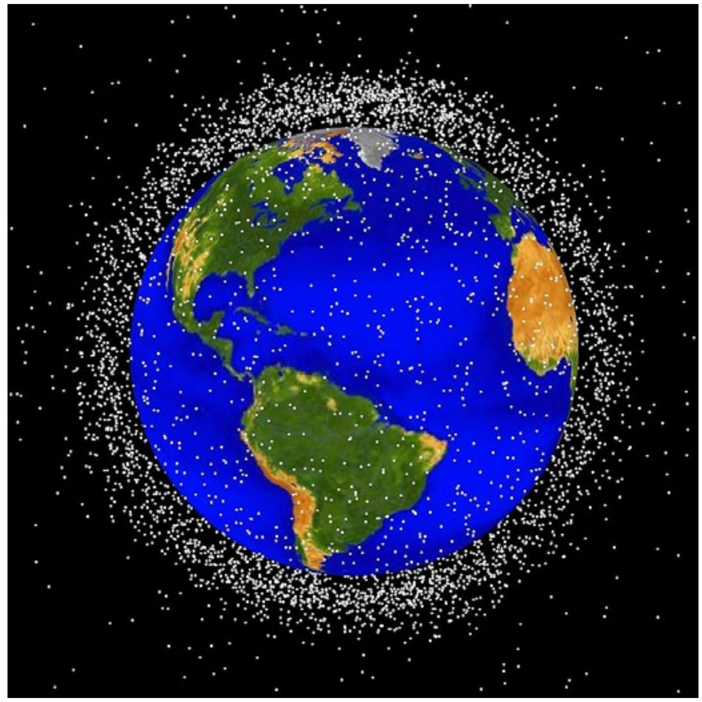
3 "UCS Satellite Database," Union of Concerned Scientists, updated January 1, 2022, https://www.ucsusa.org/resources/satellite-database; and "NSR Report: 24,700 Satellites to Be Ordered and Launched by 2030," Northern Sky Research, June 30, 2021, https://www.nsr.com/nsr-report-24700-satellites-to-be-ordered-and-launched-by-2030/.

4 2022 *Challenges to Security in Space: Space Reliance in an Era of Competition and Expansion*, Defense Intelligence Agency, March 2022, 36, https://www.dia.mil/Portals/110/Documents/News/Military_Power_Publications/Challenges_Security_Space_2022.pdf.

The current state of STM can be more aptly described as space situational awareness (SSA), or the mere knowledge of objects in orbit. Global actors (including national governments, corporations, and international organizations) track space objects and notify satellite operators when the probability of collision is notable. While collision avoidance maneuvers are standard when there is a one in ten thousand chance of collision, it is ultimately up to the operators to determine whether and when they will move.[5] The limits of this decentralized approach to SSA were illustrated in September 2019 when a European Space Agency satellite veered off path to avoid a Starlink satellite whose operator missed an email notification signaling a high probability of collision.[6]

It is no longer sufficient to know the location of spacecraft and space debris; instead, it is imperative to have a common understanding of and management over maneuver in a congested environment.[7] As space activity proliferates, the increased risk of collision between spacecraft and with space debris jeopardizes national security imperatives. Outer space underpins the success of US and allied military operations, with satellites providing crucial intelligence and communications services to the warfighter.[8]

Competitors like China and Russia recognize this and are growing their operational space fleets and increasing their presence in outer space.[9] While sustainable growth is welcomed, hostile capabilities threaten free and open access to space, as was seen most recently in November 2021 when a Russian anti-satellite (ASAT) test resulted in more than one thousand five hundred fragments of debris.[10] The first-ever collision between two satellites occurred in February 2009 when an inactive Russian communications satellite (Cosmos 2251) collided with a satellite operated by US-based Iridium Satellite LLC, causing more than two thousand pieces of debris, much of which will remain in orbit for decades.[11] Such collisions will only become more common as launch costs decrease, increasing the number of satellites entering Earth's orbit. Collisions disrupt US and allied government and military services and can threaten the sustainable use of outer space in the long term.[12]



Representation of crowding in Earth's orbit with satellites and other orbital debris. Source: NASA, February 1, 2005, https://commons.wikimedia.org/wiki/File:Debris-LEO1280.jpg

Purpose

This analysis advances the position that the United States should urgently lead on a globally coordinated policy framework for STM, else the space domain will remain on an

5 Nicholas Eftimiades, "The National Security Implications of Small Satellites," Atlantic Council, May 5, 2022, https://www.atlanticcouncil.org/event/the-national-security-implications-of-small-satellites/.

6 Jonathan O'Callaghan, "SpaceX Declined to Move a Starlink Satellite at Risk of Collision with a European Satellite," *Forbes*, September 2, 2019, https://www.forbes.com/sites/jonathanocallaghan/2019/09/02/spacex-refused-to-move-a-starlink-satellite-at-risk-of-collision-with-a-european-satellite/.

7 Neel V. Patel, "To Solve Space Traffic Woes, Look to the High Seas," *MIT Technology Review*, August 23, 2021, https://www.technologyreview.com/2021/08/23/1032386/space-traffic-maritime-law-ruth-stilwell/.

8 Bill Posey, "Space: The Ultimate High Ground," *Space News*, February 24, 2014, https://spacenews.com/39613space-the-ultimate-high-ground/.

9 *2022 Challenges to Security*, III.

10 Deganit Paikowsky, "Why Russia Tested Its Anti-Satellite Weapon," *Foreign Affairs*, December 26, 2021, https://foreignpolicy.com/2021/12/26/putin-russia-tested-space-asat-satellite-weapon/.

11 Brian Weeden, "2009 Iridium-Cosmos Collision Fact Sheet," Secure World Foundation, November 10, 2010, https://swfound-staging.azurewebsites.net/media/205392/swf_iridium_cosmos_collision_fact_sheet_updated_2012.pdf.

12 Scientists predict that the accumulation of debris could eventually cause the Kessler Syndrome, a chain reaction of space debris rendering outer space unusable. Emma Thorpe, "Space Debris Removal: Importance, Today's Methods & Innovative Spacecrafts," *Orbital Today*, March 30, 2022, https://orbitaltoday.com/2022/03/30/space-debris-removal-importance-todays-methods-innovative-spacecrafts/.

unsustainable path endangering national imperatives. The authors consider the role of key stakeholders involved in STM, identify the elements required to lay the foundation for progress on this issue set, and advance policy recommendations to help guide a comprehensive approach to STM. **STM here is defined as the ability of international and national authorities to track spacecraft and space debris, to regulate where space operators position their spacecraft, and to oversee debris mitigation and remediation efforts.**

THE ECOSYSTEM OF STM

A policy framework for STM will require close coordination between national and international government and commercial entities from the outset.

International coordination

More than twenty spacefaring nations (those with launch capabilities) exist today, in stark comparison to three such nations at the height of the US-Soviet space race in 1966. Many more national and subnational entities have active satellites.[13] As space launch and systems costs decrease, the number of national space programs will continue to skyrocket. An effective framework for STM must build a community standard for those already acting in the space domain and those expected to join soon. Leveraging its technological edge in space, the United States should lead in promoting global standards for STM, just as it did for air traffic control.

The United Nations Committee on the Peaceful Uses of Outer Space adopted guidelines in 2019 for long-term space sustainability, but they lacked real consequences for transgression.[14] The United States can model positive behavior and go a step further by shaming those who do not follow. In April 2022, the United States announced a national commitment not to conduct direct-ascent ASAT testing, referencing Russia's destructive ASAT missile test in November 2021 and a similar Chinese test in 2007.[15] This decision signals the value of space sustainability and further denounces ASAT testing on the global stage, differentiating US standards from those of Russia and China without sacrificing needed US counterspace capabilities. The United States could further find ways to hold accountable actors who do not use space responsibly. For example, the

Astronaut Dale A. Gardner, getting his turn in the Manned Maneuvering Unit, prepares to dock with the spinning WESTAR VI satellite during the STS-51A mission. Source: NASA, August 7, 2017, https://www.nasa.gov/audience/foreducators/spacesuits/historygallery/shuttle-nov84a.html

Federal Communications Commission's (FCC's) regulation of frequency licensing within the United States can be wielded as a punishment. The FCC is not required to protect a foreign nation's spectrum—or access to radio frequencies critical to space communications—so it could give away spectrum rights in response to malign behavior.

While unilateral action can set a strong international precedent, multilateral dialogue is required for a global issue like STM. The United States can work within the international community to put forth shared objectives for space sustainability. Effective SSA on a global scale will be a preliminary step toward any STM framework. The Space Data Association provides a promising model, as it "collates independently pooled data from operators to prevent collisions."[16] However, participants opt into the program, limiting its effectiveness.[17] Discussing ways

13 "UCS Satellite Database."

14 Editorial Board, "The World Needs to Set New Rules in Space," *Financial Times*, December 9, 2021, https://www.ft.com/content/20fb8386-6ce1-4e54-8955-9f5dab3824ea.

15 "Fact Sheet: Vice President Harris Advances National Security Norms in Space," White House, April 18, 2022, https://www.whitehouse.gov/briefing-room/statements-releases/2022/04/18/fact-sheet-vice-president-harris-advances-national-security-norms-in-space/.

16 "Why Join?" Space Data Association, accessed July 1, 2022, https://www.space-data.org/sda/why-join/.

17 "Space Data Association," accessed July 7, 2022, https://www.space-data.org/sda/.

A Falcon 9 rocket launches at Cape Canaveral Air Force Station in 2019. The launch, supported by the 45th Space Wing, includes upgrades to the Starlink broadband network. Source: Airman 1st Class Zoe Thacker, U.S. Air Force, November 11, 2019.

to formalize or incentivize participation in space data-sharing organizations can help maximize the value of these programs. Additionally, international agreements to deorbit old rocket launchers and defunct satellites can help clean up existing space junk. The European Space Agency is championing the world's first-ever active debris removal system, and the international community should continue developing deorbiting capabilities and conducting assessments on the highest-risk areas to inform capability development.[18]

While the United States should largely focus its efforts on likeminded nations—namely, its allies and partners—there may be areas for limited cooperation with China, Russia, and other noncooperative actors. Space debris poses a great risk to all space activity, so starting the conversation with a shared vulnerability may elicit some cooperation from China and Russia.[19] However, it is unknown whether such cooperation would extend to data sharing and other essential elements of STM. Nonetheless, an STM model is possible without buy-in from every single actor, as was seen in the air domain: The Soviet Union avoided membership in the International Civil Aviation Organization (ICAO)—established in 1947—until 1970, and China did not take part until 1971.

Public-private collaboration

Public and private space operators all agree on one thing: "satellite collisions are bad for business, and bad for space."[20] Commercial space companies can and should be included in conversations on STM policy, especially as they are at the forefront of today's space developments and will benefit from protecting the future growth of the space sector.[21] A notice of proposed rulemaking (NPRM) is one avenue to incorporate industry in broader policy making discussions when an administration is preparing to issue regulation. Moreover, in

18 "ESA's Active Debris Removal Mission: e.Deorbit," European Space Agency, May 31, 2016, https://www.esa.int/ESA_Multimedia/Videos/2016/05/ESA_s_active_debris_removal_mission_e.Deorbit; and Daniel Hoffpauir, ed., "Space Debris: Understanding the Risks to NASA Spacecraft," National Aeronautics and Space Administration, last updated April 7, 2020, https://www.nasa.gov/offices/nesc/articles/space-debris.

19 Robert A. Manning, "Engagement Reframed #8: How to Avoid Anarchy in Space," Atlantic Council, June 16, 2022, https://www.atlanticcouncil.org/content-series/engagement-reframed/engagement-reframed-8-how-to-avoid-anarchy-in-space/.

20 Neel V. Patel, "Satellite Crashes Will Plague Us Unless We Manage Space Traffic Better," *MIT Technology Review*, September 6, 2019, https://www.technologyreview.com/2019/09/06/102675/satellite-crashes-will-plague-us-unless-we-manage-space-traffic-better/.

21 Sita Sonty et al., "Herding Rockets: Improved Space Traffic Management Will Accelerate Industry Growth," *Space News*, May 11, 2022, https://spacenews.com/op-ed-herding-rockets-improved-space-traffic-management-will-accelerate-industry-growth/.

the United States, industry actors often provide comments in forums facilitated by the White House's Office of Science and Technology Policy (OSTP). Companies can also engage with the US government through organizational bodies promoting a mix of industry and academic advisers. One such model is the National Space Council Users' Advisory Group, which ensures that industry and non-federal stakeholders are represented at the national level.[22]

A shared interest in minimizing satellite collisions could support a US mandate to ensure spacecraft meet minimum safety standards. Such mandates must be designed to minimize the compliance cost to industry in order to maximize broad adoption. For example, while the US government might require spacecraft to demonstrate widely available (and cheaper) capabilities, it should incentivize tougher (and more costly) capabilities like deorbiting. This will set a standard that can be adopted internationally and does not leave small stakeholders and start-ups on the sidelines. The automotive industry provides an apt example: Seat belts did not exist until the government mandated them—and now no one will buy a car without seat belts. This policy change did not cost the government a dime, and—while it resulted in short-term resistance—everyone from consumers to insurance companies to the automotive industry benefitted in the long term.

Commercial actors already engage in SSA and STM conversations. Several industry players have already signed onto best practices for STM. For example, the Space Safety Coalition's 2019 "Best Practices for the Sustainability of Space Operations" was endorsed by myriad space industry players—including companies leading in deorbiting, space launch, and in-orbit satellite services—and included a recommendation to "strive to deorbit all spacecraft after their orbital life."[23] Moreover, commercial space is well-suited to tackle many of the technical challenges of STM, with "companies eager to provide necessary data and analytic services to government and commercial space operators."[24] However, while industry actors are able and willing to fill technological gaps, the current regulatory vacuum causes unpredictable market signals for solving issues like space debris.

PRINCIPLES FOR REGULATING STM

The global community has been slow to develop a common set of rules for—or understanding of—STM despite the urgent need to develop regulations and support capabilities to manage proliferating spacecraft and debris. The following elements should form the basis of any STM deliberations.

1. Define terms.
There must be consensus on what constitutes STM—both globally and within the US interagency—and how to define related lexicon like "space object" and "space domain awareness," which have implications for STM policy. While some experts see STM as similar to SSA, acting as an information service to satellite operators, others compare STM to air traffic management, which designates an external authority to have control over all operators. As stated, this paper defines STM as the ability of international and national authorities to track spacecraft and space debris, to regulate where space operators position their spacecraft, and to oversee debris mitigation and remediation efforts.

2. Establish minimum standards of conduct.
An effective framework for STM must consider guidelines for spacecraft pre-launch and once in orbit, as well as designate responsibility for derelict satellites and space junk. Whereas the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies—commonly referred to as the Outer Space Treaty—forms the basis of international space law, it was formulated in an era defined by few space actors and limited space capabilities, and it lacks proper consideration of traffic management and collision avoidance. This regulatory gap provides the opportunity for space entities to write the rules on the launch and maneuver of satellites. For example, SpaceX executives have proposed that, as satellites raise their orbits, they should be required to move around satellites already in the orbits they are passing through.[25] While pragmatic in concept, this becomes difficult to enforce when considering both the size of satellite constellations and the scope or duration of their missions: Should a mega-constellation with a multiyear mission be required to maneuver when crossing paths with a

22 "National Space Council Users' Advisory Group (NSpC UAG)," National Aeronautics and Space Administration, accessed July 7, 2022, https://www.nasa.gov/content/national-space-council-users-advisory-group.

23 "Best Practices for the Sustainability of Space Operations," Space Safety Coalition, September 16, 2019, https://spacesafety.org/best-practices/.

24 Charles Beams, "Why Is NOAA Not Taking Space Traffic Management Seriously?" *Forbes*, January 28, 2022, https://www.forbes.com/sites/charlesbeames/2022/01/28/why-is-noaa-not-taking-space-traffic-management-seriously/?sh=68dbc489130f.

25 Jeff Foust, "Space Community Ponders Right-of-Way Rules for Space Traffic," *Space News*, September 19, 2021, https://spacenews.com/space-community-ponders-right-of-way-rules-for-space-traffic/.

single satellite on a monthlong endeavor? Questions like this must be considered in international discussions.

Prior to launch, national and international governing bodies might consider confining satellites that lack maneuvering capability to specific altitudes. This proactive measure could help avoid collision with national assets at notable altitudes—400 kilometers, where the International Space Station (ISS) is currently situated, provides a present-day benchmark. This measure is complicated by the fact that commercial and research satellites can provide dual-use capabilities or otherwise contribute to US and allied security objectives.

Moreover, when operating above a specified altitude, spacecraft should be required to meet more stringent safety requirements. The altitude requirement today might be set at above the ISS or 400 kilometers, but this measure should remain flexible as manned spacecraft become commonplace. Space operators acting above the specified altitude should report their planned maneuvers to an international coordinating authority to preempt collisions. Maneuvers in space should be announced like maneuvers in other domains. Additionally, spacecraft should be required to have propulsion and reliable communication, which allow a satellite to maneuver and remain under positive control, respectively, thereby preventing accidental or unstoppable collisions.

3. Assign liability.

To manage and protect national space assets, accountability must be assigned for both manmade and naturally occurring space debris. Over the past two decades, trackable orbital debris has increased by more than 80 percent.[26] Moving in excess of 15,000 miles per hour, even minor debris poses an existential threat to manned and unmanned missions.[27]

The disposal of defunct satellites to "graveyard orbits," which are orbits distant from commonly used ones, is required to clean up Earth's orbits.[28] Spacecraft should have end-of-life provisions for moving into a graveyard orbit.[29] In 2019, the US government revised the Orbital Debris Mitigation Standard Practices (ODMSP), reaffirming an earlier guideline that operators remove satellites from operational orbits within twenty-five years of the end of their operational mission.[30] While widely accepted as an international standard, space development outpaces this standard and makes it obsolete in the current operating environment.[31] Moreover, accountability becomes complicated when handling the debris of non-collaborative operators like China and Russia. An international discussion could help refine such guidelines for space debris mitigation and remediation.

View of the SPARTAN 201 satellite on the Remote Manipulator System (RMS) arm end effector, during retrieval of the satellite. Source: NASA, December 15, 2010.

4. Distinguish between orbits.

STM considerations differ in geosynchronous equatorial orbit (GEO). While low-Earth orbit (LEO) satellites move relative to the Earth at any given moment, GEO satellites stay in one position relative to a specific location on Earth. To launch a satellite to GEO, a company or nation must apply to the International

26 Wainscott-Sargent, "Peeling Back the Onion."

27 Supantha Mukherjee, "Q+A What Is Space Debris and How Dangerous Is It?," Reuters, November 16, 2021, https://www.reuters.com/lifestyle/science/qa-what-is-space-debris-how-dangerous-is-it-2021-11-16/.

28 "Graveyard Orbits and the Satellite Afterlife," National Environmental Satellite Data and Information Service, US Department of Commerce, October 31, 2016, https://www.nesdis.noaa.gov/news/graveyard-orbits-and-the-satellite-afterlife.

29 Walter Scott, "Preserving the Space Environment for Future Generations," Maxar Technologies, September 18, 2019, https://blog.maxar.com/tech-and-tradecraft/2019/preserving-the-space-environment-for-future-generations.

30 National Aeronautics and Space Administration, *Orbital Debris Mitigation Standard Practices*, November 2019 Update, November 2019, 2, https://orbitaldebris.jsc.nasa.gov/library/usg_orbital_debris_mitigation_standard_practices_november_2019.pdf.

31 Benjamin Staats, "There's No Perfect Space Traffic Management Framework," *SpaceNews*, June 23, 2022, https://spacenews.com/op-ed-theres-no-perfect-space-traffic-management-framework/; and Christopher T. W. Kunstadter, "What Keeps Space Insurers Up at Night?" *Air and Space Lawyer* 34 (3) (2022): 10–11, https://www.iuai.org/common/Uploaded%20files/Bulletins%202022/ASL_v034n03_Kunstadter.pdf.

Telecommunications Union (ITU) for a slot. While all slots are essentially spoken for today, advanced space technology is decreasing the traditional amount of space required between two active satellites, thus presenting openings for new actors. However, slots are often filled by "paper satellites," or spacecraft unlikely to be manufactured or launched but instead meant to hold a spot in line. Working within the parameters of GEO, an STM framework must consider how to maximize equitable access to space while minimizing risk to current operators.[32]

As activity moves into xGEO or cislunar space, the United States and its allies have an opportunity to proactively address traffic management and construct a framework that reflects the reality of dual-use space activity.[33] While the lunar orbit is not often trafficked, fifty payloads are expected to reach the Moon by 2030.[34] Moreover, US adversaries recognize that satellites beyond GEO are harder to track and monitor, and that cislunar space can thus be used to hold reserve satellites for LEO operations.[35] The US military is beginning to develop SSA models for cislunar space, as the vast distance from Earth-based sensors makes tracking difficult beyond GEO.[36] The Air Force Research Laboratory is currently pioneering the Cislunar Highway Patrol System (CHPS), which is designed to improve the US Space Force's ability to "track and identify artificial objects operating at lunar distances and beyond." CHPS spacecraft will launch in 2025 to experiment with space traffic procedures for operating near the Moon or other cislunar areas.[37]

5. Allocate responsibilities and authorities.
STM is a global issue requiring a global response. To realize any of the above proposals, an international coordinating authority must first be empowered to promote dialogue and advance norms and regulations for national and subnational space operations. To establish a coordinating authority, discussions should begin in existing international fora like the United Nations Office for Outer Space Affairs (UNOOSA). Eventually, a coordinating authority might expand or mirror existing governing bodies. For example, space management might be best executed by extending the ICAO's area of responsibility to include outer space, or through the creation of "an ICAO-like organization to monitor space activity."[38]

Domestically, a lead US agency must be designated to represent national equities on the global stage. The Office of Space Commerce, within the US Department of Commerce (DoC), is often identified as the right agency to lead the charge.[39] In June 2018, the White House issued "Space Policy Directive–3: National Space Traffic Management Policy" calling for a "new approach" to STM and charging the DoC with the responsibility of data-sharing and collision-avoidance support services.[40] This aligns with the Fiscal Year 2023 President's Budget request, which includes a $78 million increase from the 2021 enacted budgetary level for the DoC to expand civil SSA and "improve real-time tracking and reporting of space objects and debris."[41] In August 2022, the DoC and the US Department of Defense (DoD) are expected to sign a memorandum of agreement to support the DoC's leadership on a civil structure for SSA.[42] A

32 Louis de Gouyon Matignon, "Orbital Slots and Space Congestion," Space Legal Issues, June 8, 2019, https://www.spacelegalissues.com/orbital-slots-and-space-congestion/.

33 Jessy Kate Schingler, Victoria Samson, and Nivedita Raju, "Don't Delay Getting Serious About Cislunar Security," *War on the Rocks*, July 6, 2022, https://warontherocks.com/2022/07/dont-delay-getting-serious-about-cislunar-security/.

34 Luke Dormehl, "Why the Moon Needs a Space Traffic Control System," *Digital Trends*, March 11, 2022, https://www.digitaltrends.com/space/lunar-space-junk-tracking/.

35 *2022 Challenges to Security*, 36.

36 Ibid.

37 "Cislunar Highway Patrol System (CHPS)," Air Force Research Laboratory, accessed July 7, 2022, https://afresearchlab.com/technology/cislunar-highway-patrol-system-chps/.

38 Clementine G. Starling et al., *The Future of Security in Space: A Thirty-Year US Strategy*, Atlantic Council, April 11, 2021, https://www.atlanticcouncil.org/content-series/atlantic-council-strategy-paper-series/the-future-of-security-in-space/.

39 *Space Traffic Management: Assessment of the Feasibility, Expected Effectiveness, and Funding Implications of a Transfer of Space Traffic Management Functions*, Report by a Panel of the National Academy of Public Administration for the Office of Space Commerce, the Department of Commerce, August 2020, https://s3.us-west-2.amazonaws.com/napa-2021/studies/united-states-department-of-commerce-office-of-space-commerce/NAPA_OSC_Final_Report.pdf.

40 "Space Policy Directive–3 of June 18, 2018, National Space Traffic Management Policy," Presidential Documents, Federal Register 83 (120) (June 21, 2018), https://www.govinfo.gov/content/pkg/FR-2018-06-21/pdf/2018-13521.pdf; and *Space Traffic Management: Assessment of the Feasibility*.

41 "Budget of the U.S. Government: Fiscal Year 2023," Office of Management and Budget, March 2022, https://www.whitehouse.gov/wp-content/uploads/2022/03/budget_fy2023.pdf.

42 Theresa Hitchens, "SPACECOM, Commerce Wrapping Up Framework Accord on Space Surveillance," *Breaking Defense*, June 27, 2022, https://breakingdefense.com/2022/06/spacecom-commerce-wrapping-up-framework-accord-on-space-surveillance/.

A Seaman Operations Specialist monitors vessel traffic in the New York Harbor before a blackout darkened the northeast in 2003. Source: PA2 Mike Hvozda, U.S. Coast Guard, August 14, 2003.

civil SSA system, relying on the commercial sector's diverse and complementary SSA capabilities, would further allow the DoD and, specifically, the US Space Force to focus on space domain awareness (SDA), which reflects a mindset shift toward space as a warfighting domain requiring better SSA for security purposes.[43] In addition, some experts advocate for the formation of a separate all-space agency to synthesize "diverse perspectives and rapidly resolving space-related issues across participating departments and agencies."[44] Should such an agency come to fruition, it will lend the necessary top cover to the STM efforts within the DoC.

LESSONS FROM OTHER DOMAINS

In paving the way forward for STM, policy makers may draw parallels from the traditional domains of air and maritime. The air domain offers a promising model for an international coordinating authority, with each nation's equivalent of the US Federal Aviation Administration (FAA) representing national interests on the global stage through the ICAO. Additionally, visual flight rules in the air domain—which ensure an aircraft operates in clear visual conditions and prevents commercial flights around designated areas like airports in special weather conditions—could translate into guidance for spacecraft confined to specified altitudes. However, the dual-use nature of space activity, blurring the distinction between commercial and military activity, makes the civil air model an imperfect fit for information sharing and traffic management.

Additionally, maritime data-sharing models can inform a framework for STM. The Automatic Identification System (AIS) was created by the United States and its allies and partners, and it requires ships of a certain size to provide geographic locational data.[45] AIS was initially a coalition of the willing: Ships

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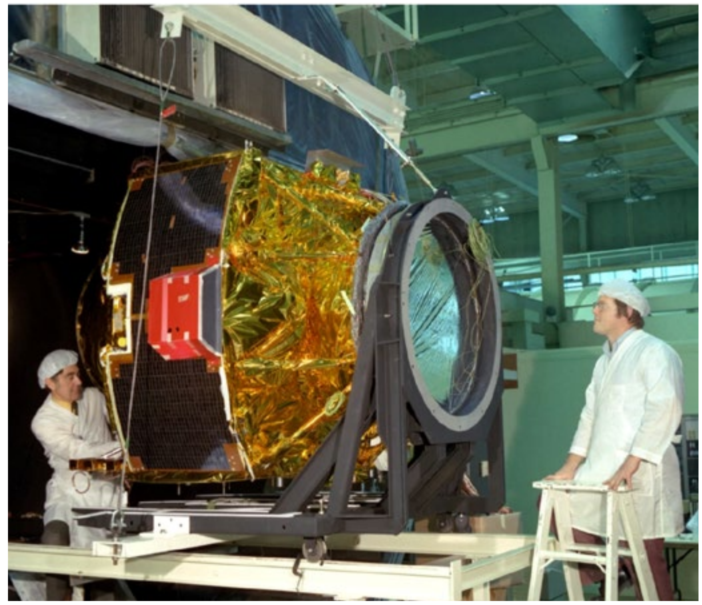
43 *Space Situational Awareness: Guiding the Transition to a Civil SSA Capability*, US House of Representatives Committee on Science, Space, and Technology, 117th Cong. (April 29, 2022) (testimony of Kevin M. O'Connell, founder, Space Economy Rising, and former director, Office of Space Commerce), https://republicans-science.house.gov/_cache/files/4/2/42d7a9ad-c765-4c26-8b3c-911c4ed8bb24/3E41EC3CB3EB78C4D9B037679362113D.2022-05-12-o-connell-testimony.pdf; and Sandra Erwin, "Air Force: SSA Is No More; It's 'Space Domain Awareness,'" *Space News*, November 14, 2019, https://spacenews.com/air-force-ssa-is-no-more-its-space-domain-awareness/.

44 Steven J. Butow et al., *State of the Space Industrial Base 2020*, July 2020, https://www.nasa.gov/sites/default/files/atoms/files/state-of-the-space-industrial-base-2020-report_july-2020_final_0.pdf; and John M. Olson et al., State of the Space Industrial Base 2021, November 2021, https://newspacenm.org/wp-content/uploads/2021/11/Space-Industrial-Base-Workshop-2021-Summary-Report-Final-15-Nov-2021c.pdf.

45 MarineTraffic, "What Is the Automatic Identification System (AIS)?" accessed July 17, 2022, https://help.marinetraffic.com/hc/en-us/articles/204581828-What-is-the-Automatic-Identification-System-AIS-.

that agreed to use AIS were initially given updated National Oceanic and Atmospheric Administration (NOAA) map systems and weather data for free. AIS provides a promising model for space operators to build upon. However, automated transponders can make a satellite vulnerable to adversarial targeting and would require further security safeguards.

Apart from traditional transport and commerce domains, a tested model for global data sharing can be found in weather monitoring. STM and weather forecasting both concern data with value outside of national boundaries. To arrive at current practices for weather monitoring, the international community long deliberated on a model for coordinating data and deciding on what must be openly available, obligating warnings and alerts, and considering underlying ethical concerns. Moreover, weather services include a mix of public- and private-sector actors, similar to the space community today. Investigating early conversations on data sharing for weather purposes can help inform today's STM discussions.[46]



Engineers inspect a satellite from the communications technology satellite program prior to its launch. Source: NASA, August 27, 2009.

TECHNICAL COMPONENTS OF STM

STM requires the capability to track space objects, communicate between space operators, and remove space junk or debris. US and allied space operators must develop these technical capabilities to support the space regulatory environment. While the US government is investing in capabilities for tracking and, when necessary, removing space objects from orbit, the United States still lacks a viable technical capability for STM.[47] Currently, there are no integrated systems that can provide comprehensive domain awareness on par with the air or maritime domains for the space domain, which is more complex than the other two domains.[48] The US Space Force is currently developing a number of domain awareness tools, including the Deep Space Advanced Radar Concept (DARC), which is used to detect and track deep space objects in GEO, and the Space Fence, a radar making one hundred and thirty thousand observations per day in LEO.[49]

US Space Command is tracking thirty-five thousand space objects, representing just 0.01 percent of objects orbiting Earth and only a subset of the debris that can harm spacecraft.[50] Situational awareness sensors underlie the US government's ability to track space objects, and adding additional sensors on Earth and in space can support an enhanced SSA capability.[51] Next, a reliable mechanism for communication with and between spacecraft is required to connect with space traffic control. Finally, debris removal systems must be created to collect and deorbit debris, prioritizing those large objects that present the highest risk to spacecraft. The United States needs a number of technical abilities for enhanced debris removal capabilities, including passive and active aids for tracking satellites and finding dead satellites. Technologies like optical telescopes, radars, GPS or equivalents, and satellite receivers

46 See remarks by Georgia Institute of Technology's Mariel Borowitz in Secure World Foundation, "Bridging the Transatlantic Gap on Space Traffic Management," June 27, 2022, YouTube video, https://www.youtube.com/watch?v=A689KB4Bz8M.

47 Marshall H. Kaplan and Gurpartap Sandhoo, "The Challenges of Space Traffic Management," *SpaceNews*, February 18, 2022, https://spacenews.com/op-ed-the-challenges-of-space-traffic-management/.

48 Ibid.

49 Yasmin Tadjdeh, "U.S. Strengthening Space Domain Awareness," *National Defense Magazine*, July 30, 2021, https://www.nationaldefensemagazine.org/articles/2021/7/30/us-strengthening--space-domain-awareness.

50 Kaplan and Sandhoo, "The Challenges."

51 Bhavya Lal et al., "Global Trends in Space Situational Awareness (SSA) and Space Traffic Management (STM)," Institute for Defense Analyses, April 2018, https://www.ida.org/-/media/feature/publications/g/gl/global-trends-in-space-situational-awareness-ssa-and-space-traffic-management-stm/d-9074.ashx.

and transmitters will help determine a satellite's location and whether it is in operational use. Standardized "hooks" or attachment points will help capture known dead satellites. To achieve these technological advancements, the United States and the international community at large must invest in research and development for STM.

RECOMMENDATIONS AND CONCLUSION

An international framework for STM is crucial to protecting a future of security and prosperity in the space domain. Accordingly, the following steps are recommended in order of priority:

Recommendation #1: The United States and its allies should engage the broader international community to authorize an international coordinating authority to lead on STM. This could be through the expansion of an existing organization, such as the ICAO, or the creation of a new organization with necessary authorities.

Recommendation #2: Given the proposed funding and granted authorities for the DoC on STM matters, the US Congress should examine whether the Office of Sp ace Commerce is equipped to lead on STM matters, ensuring it has the correct structure, mandate, and funding to accomplish effective oversight of national STM.

Recommendation #3: Through fora like the UNOOSA, the international community should reach consensus on the definitions of STM, SSA, and related terms. This will create baseline consensus on which to base future rules for STM.

Recommendation #4: The US government must recognize its allies and partners, as well as US and allied industries, as equal partners in STM framework deliberations. NPRMs and OSTP-facilitated fora are worthwhile mechanisms to give industry leaders a voice in the debate. Moreover, the National Space Council should conduct a survey to further elicit feedback and open a dialogue with commercial space companies and the international community on the future of STM.

Recommendation #5: The FAA's space launch licensing requirements should be updated to include requirements to report planned maneuvers, and operators should be further incentivized to demonstrate deorbiting and debris mitigation capabilities. Both these measures can help mitigate the risk of collision. The international coordinating authority could then take charge on reporting of planned maneuvers and, in the longer term, requirements for deorbiting or moving satellites to graveyard orbits.

Recommendation #6: The United States and its allies should rally the international space community to determine a common set of rules surrounding the disposal of defunct satellites. The burden should be placed on satellite operators, and solutions should prioritize the incentivization of private-sector engagement on active debris removal solutions. The US government's ODMSP provides a helpful baseline, and periodically revising this document can provide an avenue for updating international standards.

Recommendation #7: The US Congress should appropriate additional funds for research and development of capabilities relevant to effective STM, to include ground-based and space-to-space sensors and communications capabilities, passive and active deorbiting mechanisms, and the ability to track small space objects. Such efforts must be reinforced by global policy discussions on the requirements and responsibilities of spacefaring entities.

Recommendation #8: The US government should provide standards for satellites that lack maneuvering capability to be launched to orbits 400 kilometers or lower, or just below the ISS, when feasible. The 400-kilometer boundary should be reassessed on a regular basis to account for space developments to include crewed missions. The lead US agency for STM should coordinate with satellite operators and, when appropriate, assign orbital altitudes that avoid collision with major national space assets. This can be modeled off the air domain, wherein special flight rules surround designated areas like airports.

Recommendation #9: The United States should lead by example in outer space. US departments and agencies can encourage international cooperation by incentivizing positive behavior—similar to how maritime vessels using AIS were initially rewarded with free NOAA maps and weather updates—and discourage malign actions by leveraging diplomacy and all the other instruments of national power.

Achieving security, economic, and societal objectives in the twenty-first century hinges on free and open access to outer space. The current regulatory vacuum on STM leaves room for malign activity and unsustainable business practices. If space development remains on its current trajectory, and the global community fails to advance an effective STM framework, humankind will jeopardize its use of outer space, modern ways of living, and all the corresponding benefits on Earth. Now is the time to act and protect a future of security and prosperity in space.

METHODOLOGY

The authors employed a qualitative research methodology, constructed around a set of key research questions and drawing from a review of authoritative literature and spoken remarks on STM. Expert groupings were consulted on key research questions while drafting this issue brief. The study was guided by a senior advisory panel, which helped to frame and refine the key findings and recommendations.

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The authors conducted several interviews and consultations to produce this issue brief. Listed below are some of the individuals consulted and whose insights informed this issue brief.

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The analysis and recommendations presented in this issue brief represent the authors' views solely and do not necessarily represent the personal views of the individuals consulted, or the official policy or position of any department or agency of the US government, or of any other organization.

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