FROM THE HOOVER TECHNOLOGY POLICY ACCELERATOR

Space Safety and Sustainability

Part II: Recommendations

by Simone D'Amico, Tycho Bogdanowitsch, Walter J. Manuel, Yuji Takubo, and Rebecca Wang

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Executive Summary

PRESERVING THE ORBITAL COMMONS

As the global economy and national security increasingly depend on orbital infrastructure, the stability of the space environment has become crucial to modern civilization. However, the “rules of the road” have not kept pace with the exponential growth of space assets. This working paper proposes a transition from reactive crisis management to a proactive life cycle–based model for space traffic coordination (STC).

Given that US-based entities operate 75 percent of active satellites, the United States has the leverage and opportunity to establish a gold standard for space security, safety, and sustainability (4S) through three strategic pillars.

PILLAR 1: DOMESTIC POLICY (THE RULES)

The current system suffers from fragmented data and unscalable manual workflows. To address this, the US must modernize licensing and infrastructure:

- **Standardized data sharing**: Utilize the Federal Communications Commission (FCC) or similar federal licensing authority to mandate the sharing of standardized “safety bundles”—including ephemerides (trajectory data), maneuver intent (capabilities and plans), associated uncertainty information, and point-of-contact data—making such sharing a default condition for licensing.
- **Civil infrastructure**: Fully fund and operationalize a national space situational awareness (SSA) system (similar to the Traffic Coordination System for Space, or TraCSS) to serve as a neutral, standards-based backbone for the commercial ecosystem.

A Hoover Institution Essay

June 2026

PILLAR 2: DOMESTIC TECHNOLOGY (THE TOOLS)

To manage increasingly congested orbits, the US must invest in scalable, autonomous technical solutions:

- **AI-driven autonomy**: Deploy machine learning (ML) and artificial intelligence (AI) for distributed decision making, anomaly detection, and autonomous maneuver planning to reduce human operator burden.
- **Persistent tracking**: Invest in layered sensing architectures—combining ground-based and in-space assets—to maintain high-fidelity tracking of satellites and space debris.
- **On-orbit servicing**: Support technologies for active debris removal (ADR), refueling, and life extension to close the loop of the spacecraft life cycle.

PILLAR 3: INTERNATIONAL LEADERSHIP (THE GLOBAL PLAN)

Space is inherently transnational; therefore, safety standards must be exported globally:

- **Interoperable standards**: Model STC after global navigation satellite systems (GNSS) by standardizing machine-readable outputs (conjunction assessments, collision risk metrics, and coordination messages) rather than centralizing control.
- **De facto norms**: By implementing these standards at scale domestically, the US can catalyze a federated global ecosystem where international actors align with US frameworks to ensure mutual safety and economic stability.

INTRODUCTION

The space domain is no longer a distant frontier; it now underpins critical infrastructure across commerce, security, and daily life. From navigation systems and weather forecasting to global commerce and national defense, society relies heavily on a functional and predictable orbital environment. Currently, thousands of satellites occupy low Earth orbit (LEO) and geostationary orbit (GEO), with tens of thousands more projected to launch within the decade—a surge that necessitates a more robust framework for space traffic coordination (STC).

However, as highlighted in “Space Safety and Sustainability, Part I: Past and Present Practices,” national and international rules of the road have not kept pace with the rapidly expanding volume of satellites and space activities.[1] This disconnect has created a precarious environment where blind spots and insufficient coordination increase the risk of a collision cascade—a chain reaction of crashes that could not only devastate vital civil, commercial, and military infrastructure but also render key regions of space unusable for generations. At present, there is a critical absence of a coordinated global effort to tackle this dangerous possibility.[2]

Given this context, the United States is uniquely positioned to lead. Because US-based entities operate roughly 75 percent of all active satellites, US domestic policies act as a global compass. By taking decisive action now, the US can establish gold standards for orbital safety through practical implementation rather than waiting for years of international negotiation.[3]

To safeguard the present and future of the shared orbital commons, it is imperative to take a life cycle–based approach to space traffic that promotes business creation. This model treats a satellite's journey as a continuous system, from safe entry and autonomous flight to responsible disposal, much as ground transportation systems manage automotive vehicles from licensing and entry onto roads to active navigation and eventual retirement. Such a paradigm shift evolves STC from a reactive, crisis management mindset to a proactive, scalable infrastructure jointly developed by government and industry.

This vision requires a unified strategy across three strategic pillars:

1. **Domestic policy—the rules**: Establishing clear, enforceable rules for data sharing and transparency
2. **Domestic technology—the tools**: Investing in AI-driven autonomy at the edge, advanced sensing, active debris removal, and orbital lifetime prolongation
3. **International leadership—the global plan**: Adopting and exporting US standards at scale to create a predictable and stable global orbital order

By aligning domestic policy modernization with sustained technology investment and a clear international strategy, the US can seize the first-mover advantage to implement a life cycle–based model of space safety that ensures safe entry, predictable operations, maintained controllability, and responsible exit from the space domain.

PILLAR 1: DOMESTIC POLICY (THE RULES)

The US space ecosystem is scaling rapidly, but its policy foundations have not kept pace. Today's system relies on inconsistent data sharing and a fragmented coordination infrastructure, forcing operators to adopt manual workflows that cannot scale to increasingly congested orbits.[4] As constellations grow and conjunction alerts—warnings that two satellites may come dangerously close or collide—increase, the lack of standardization and shared infrastructure is becoming a primary driver of operational risk to US national and economic security. Addressing this requires targeted policy action that establishes both clear rules for data sharing and a common technical backbone for coordination. Together, the modernization of licensing and the establishment of civil coordination infrastructure form a complementary policy stack: the first sets rules for standardized, actionable data sharing, and the second provides a platform for coordination, integration, and service delivery. This combination creates a scalable foundation for STC, reducing uncertainty, enabling automation, supporting a competitive commercial ecosystem, and positioning the United States to lead globally through the implementation of effective domestic policy.

PROBLEM 1: NON-STANDARDIZED SHARING OF SATELLITE LOCATION DATA

A core issue in today's environment is the lack of consistent, actionable data sharing across operators. Many satellite owners either do not share satellite location data (ephemerides) or provide data in non-standard formats, often without uncertainty bounds (covariance), the satellite's maneuvering capabilities, its maneuver plans, or reliable contact information.[5] This creates ambiguity in conjunction assessments, slows coordination, and limits the ability to automate collision avoidance. In practice, operators sometimes struggle to even identify or contact responsible parties, while incomplete information around which satellites are maneuverable further complicates decision making.

Solution: Modernization of Domestic Space Licensing

To address this, the US should modernize domestic space licensing by using federal licensing authority as the primary policy lever for enforceable, standardized space safety requirements. Congress should clarify which agency or agencies should be responsible for implementing these requirements, with the Federal Communications Commission (FCC) serving as one potential near-term vehicle given its existing role in satellite licensing and orbital debris review. Ephemeris sharing should be a default license condition for all US-licensed operators and should be expanded into a standardized "safety bundle" that includes ephemerides, covariance or uncertainty envelopes, maneuver-intent indicators, planned maneuvers, and key spacecraft parameters, such as maneuverability status, nominal attitude mode, spacecraft size, and ballistic coefficient. Operators should also be required to maintain up-to-date, validated point-of-contact information aligned with international frameworks, including UN registration practices, to enable rapid and reliable coordination when needed. All safety-critical data should be machine-readable and interoperable to support automated conjunction screening, operator-to-operator coordination, and future autonomous traffic management systems.

In parallel, the relevant federal licensing authority should codify rules-based coordination standards informed by industry best practices, including those developed by the American Institute of Aeronautics and Astronautics (AIAA) Space Safety Coalition.[6] These standards can translate emerging responsible behaviors, such as routine ephemeris sharing, covariance disclosure, maneuver intent signaling, and predictable coordination pathways, into binding requirements that support increasingly autonomous operations. Congress should support and oversee ongoing licensing modernization efforts, including the FCC's Space Modernization for the 21st Century Notice of Proposed Rulemaking, while also resolving broader questions about which agency is best positioned to regulate space safety and sustainability over the long term. These efforts should build on existing orbital debris mitigation requirements, including the FCC's five-year post-mission disposal rule for applicable LEO spacecraft, and extend licensing modernization toward standardized data sharing, validated contact information, interoperable autonomy rules, and enforceable coordination standards. Together, these actions would establish a clear regulatory foundation for transparency, interoperability, accountability, and automation in US-licensed space operations.

PROBLEM 2: FRAGMENTED CIVIL INFRASTRUCTURE

Even with improved data-sharing requirements, coordination cannot scale without a shared infrastructure layer. Today, operators rely on a fragmented mix of government catalogs, proprietary services, and informal coordination practices, leading to inconsistent assessments and duplicated effort. This lack of a common operating picture limits the effectiveness of data sharing and increases operational uncertainty.

Solution: Structured Funding Toward a Governmental Space Situational Awareness Infrastructure

To address this, the US should treat a civil SSA and STC system, such as the Department of Commerce's Office of Space Commerce (OSC) efforts with TraCSS, as critical national infrastructure analogous to air traffic control for space. Congress should provide secure and sustained funding to establish and fully operationalize a baseline national SSA/STC backbone that commercial companies can build upon from the ground and in space. This system should establish open standards, application programming interfaces (APIs), and digital information exchange protocols for conjunction assessment, maneuver coordination, and safety-critical data sharing.

Such a system should function as a data fusion flywheel, integrating government and commercial inputs to produce higher-confidence safety products, improve custody of space objects, and reduce fragmentation across the ecosystem. Importantly, it must be positioned as a baseline public service layer, not a government competitor to industry. A neutral backbone would lower barriers to entry and allow private companies to build differentiated services on top, including data analytics, autonomy tools, mission operations software, advanced conjunction assessment, and operator-specific coordination platforms. In this model, government provides a trusted, standards-based infrastructure, while industry drives innovation across a competitive ecosystem of private applications and operational tools.

Maintaining a neutral, standards-based backbone is essential for building trust, ensuring interoperability, and enabling eventual international adoption. If civil STC infrastructure becomes tied to a single operator's platform, incentives, or proprietary service terms, it will be harder to scale across operators, agencies, allies, and international partners. By contrast, an open and publicly stewarded system can provide the common technical foundation needed for automated coordination, commercial growth, and global norm setting.

PILLAR 2: DOMESTIC TECHNOLOGY (THE TOOLS)

Innovation and investment in domestic space-operations technology are critical factors for the United States to thrive in the congested and contested space environment. This entails a wide range of solutions, from passive information gathering and reactive decision making to preemptive orbital maneuvering. The incorporation of ever more sophisticated ML and AI technologies in the safety-critical environment of space is becoming increasingly important.

PROBLEM 1: UNSCALABLE GROUND OPERATIONS FOR DECISION MAKING

Given that the number of spacecraft in orbit is growing exponentially, establishing scalable coordination of space systems is an urgent problem. The emerging capabilities of AI and ML technologies offer many enticing opportunities to significantly improve the next generation of SSA/STC by enhancing sensing, autonomy, and operations. For example, AI-enabled human–spacecraft interfaces (e.g., language- and reasoning-based interfaces for maneuver generation) and autonomous tasking or operation of constellations of spacecraft could reduce operator burden and expertise requirements, supporting safe and scalable operations. The proliferation of vision-based sensors and onboard image processing could dramatically boost in-space SSA. Furthermore, ML-based methods could improve the fusion of in-space and terrestrial sensing data by handling heterogeneous measurements and uncertainty at scale, yielding more reliable custody and risk assessment.

Solution: AI-Driven Distributed Decision Making

The National Aeronautics and Space Administration (NASA), the Department of Defense (DOD), and OSC should encourage the research and development of ML/AI solutions to facilitate space security, safety, and sustainability in a distributed and scalable fashion. This includes both passive technologies (e.g., anomaly detection, uncertainty quantification, maneuver detection) and reactive decision-making technologies, such as autonomous maneuver planning for collision avoidance and operation of constellations. Such technologies accelerate the exchange of digital information among different actors, reducing the lag time from detection to critical action and thereby derisking in-orbit activities.

Beyond enabling the scalable operation of large distributed space systems, ML/AI solutions provide resilient edge autonomy that enables time-critical functions such as anomaly detection, conjunction response, and maneuver planning under communication constraints. Furthermore, AI could enable new autonomous maneuvering capabilities for spacecraft—previously almost impossible—in the context of constellation reconfiguration or in-space assembly and manufacturing.

PROBLEM 2: UNRELIABLE TRACKING OF SATELLITES AND DEBRIS

Another key issue in SSA/STC is the frequency and cadence with which each space object can be observed. Both factors affect the reliability and currency of tracking data in the space catalog. As the number of satellites in orbit grows, custodial observation of satellites and debris directly affects the quality of STC. While current state-of-the-practice approaches incorporate multimodal observation, the collection and aggregation of data from multiple sources and actors are yet to be fully developed.

Solution: Novel Sensing Technology and Data Fusion

NASA, DOD, and OSC should support investment in (a) proliferated ground-based sensing and in-space SSA assets, both opportunistic and through dedicated payloads, and (b) technologies for aggregating multisource data in orbit and on the ground.

In an increasingly populated orbital environment, achieving a high observation cadence of the space object population, including active and inactive satellites and debris, requires a layered architecture consisting of (a) proliferated ground-based sensing for broad coverage, cadence, and characterization, complemented by (b) proliferated in-space SSA assets that mitigate the geometry and latency limitations of terrestrial networks. These sensing layers will work together to provide a coherent, auditable picture of the orbit environment. The overarching data fusion layer must be designed to merge government and commercial data streams and to handle heterogeneous measurement models, varying data quality, and noncooperative behaviors. It will be able to produce consistent state/uncertainty products that can be consumed operationally (screening, tasking, anomaly detection). Key engineering priorities include scalable sensor tasking and scheduling algorithms, as well as the hardware and algorithmic development of in-space navigation and characterization technologies. A sustained investment in sensing and multisource data fusion technologies will provide higher-fidelity observations and tracking, thus reducing avoidable conjunction alarms, improving maneuver decision quality, and enabling operators to transition from reactive screening to proactive risk management.

PROBLEM 3: INCREASED COLLISION RISK FROM SPACE DEBRIS

Finally, even if active and inactive objects in space were well cataloged, some would take several years to deorbit and fall into Earth's atmosphere for disposal at the end of their lifetimes. About half of the objects around Earth are "space junk," including debris, rocket bodies, and unidentified objects. This problem is worsening as launches and orbital infrastructure increase, potentially leading to a reduction of the usable orbital domain and to increased collision risk. Therefore, to maintain a safe and sustainable space environment, it is essential to have the ability to actively prevent further cascading effects from a targeted set of satellites and debris.

Solution: On-Orbit Servicing (Inspection, Refueling, and Active Debris Removal)

NASA and DOD should focus on the agile development and demonstration of on-orbit servicing capabilities. Congress should implement and fund authorities under the Orbital Sustainability Act of 2025 (S.1898; ORBITS Act) to support debris remediation demonstrations and procurement and leverage frameworks in the Situational Awareness of Flying Elements in Orbit Act (S.428; SAFE Orbit Act) to strengthen safety, orbital lifetime prolongation, and disposal requirements.

Effective SSA and STC require a circular, life cycle–based approach to orbital traffic, combining prevention, autonomous operations, repair, and removal, much like modern ground transportation infrastructure manages automotive vehicles from entry to retirement. The proliferation of (autonomous) on-orbit servicing and refueling, with the aim of extending controllability to reduce future space traffic hazards, is necessary to prolong the lifespan of satellites, akin to preventive maintenance of a car or aircraft on Earth. These on-orbit services could include refueling, orbit raising, or other robotic-enabled repairs. Moreover, with over 14,000 spacecraft currently in orbit, over 30,000 pieces of trackable space debris, and millions more pieces of untracked debris, it is imperative that all spacecraft follow deorbit and disposal regulations. ADR missions will also be necessary to clean up existing debris or help deorbit satellites at the end of their missions. Even a piece of debris the size of a paint chip can cause catastrophic damage and potentially lead to a domino effect of collisions when traveling at seven kilometers per second. For a future of proliferated LEO mega-constellations to be possible, there simply is not enough orbital carrying capacity to leave defunct satellites and debris in orbit, making end-of-life remediation and disposal an essential part of closing out the spacecraft life cycle.

PILLAR 3: INTERNATIONAL LEADERSHIP (THE GLOBAL PLAN)

International leadership in SSA and STC will be essential to maintaining the long-term safety, stability, and sustainability of the space domain. Because orbital activity is inherently global, no single nation can effectively manage congestion, collision risk, or debris mitigation in isolation. Existing international mechanisms provide useful forums for discussion, but their largely voluntary nature limits operational consistency and enforcement. To address this gap, the United States should leverage its technical and commercial leadership to establish open, interoperable standards and operational frameworks that can serve as the foundation for a globally coordinated SSA/STC ecosystem.

PROBLEM: NON-BINDING AUTHORITY AT THE INTERNATIONAL LEVEL

Effective SSA and STC cannot be achieved through purely domestic action. Orbital regimes are inherently transnational, and risks from congestion, debris, and lack of coordination propagate across borders regardless of ownership. Yet existing international mechanisms remain largely nonbinding, limiting their ability to ensure consistent, operational execution of space safety practices.[7]

Solution: Exporting an Open SSA/STC Standard for Interoperable Global Systems

The US should leverage its first-mover advantage to establish open, unified standards of space safety outputs across different systems, similar to how the International GNSS Service (IGS), the International Civil Aviation Organization (ICAO), the International Telecommunication Union (ITU), and the International Committee on GNSS (ICG) work to support the GNSS ecosystem. Analogous forums for space safety and sustainability include the ITU, the United Nations Committee on the Peaceful Uses of Outer Space (COPUOS), and the United Nations Office for Outer Space Affairs (UNOOSA). This standardization can be achieved through active engagement in international diplomacy as well as through the proliferation of regulatory frameworks in domestic operations, given that the US maintains a leading position in the number of active satellites. The operational adoption of such frameworks can propagate outward and ultimately establish de facto international standards, particularly when implemented at scale.

GNSS demonstrates how global conformity can emerge without centralized control. Technical standardization begins at the data level through formats such as the Receiver Independent Exchange Format (RINEX), which enables universal sharing and processing of observation data across receivers, constellations, and analysis centers. This foundation supports institutions like the IGS, which aggregates global tracking data to produce precise orbit and clock products used worldwide.

These technical standards are reinforced by operational and regulatory bodies. ICAO defines performance-based navigation requirements (e.g., integrity, continuity, accuracy) that aviation systems must meet, while the ITU ensures spectrum compatibility across systems. At the coordination level, the ICG facilitates interoperability among sovereign systems such as the Global Positioning System (GPS; US), Galileo (EU), BeiDou (China), and GLONASS (Russia). Critically, no single entity governs GNSS globally. Instead, shared formats, interfaces, and performance expectations produce a system that is effectively unified in practice.

An SSA/STC system can replicate this model by standardizing outputs rather than centralizing control. The US should define open, machine-readable formats for core safety products—conjunction assessments, uncertainty bounds, maneuver coordination messages, and risk metrics—analogous to how RINEX standardizes GNSS observation measurements. In GNSS, globally distributed receivers, which are built by different manufacturers and operated by independent organizations, produce interoperable data through shared formats like RINEX, enabling aggregation by services such as the IGS into globally trusted products. This structure enables commercial innovation: Companies compete on sensors, algorithms, and services while producing interoperable outputs. Applied to SSA/STC, this allows domestic and international actors to innovate while ensuring compatibility, with US systems serving as reference implementations that others adopt.

With the US leading global satellite operations, domestic regulatory frameworks and operational systems can propagate outward, creating de facto global norms. Other spacefaring nations and actors, including the EU, China, Japan, and India, have strong incentives to align, as interoperability enhances safety, resilience, and access to shared infrastructure while preserving sovereign control over sensors and data processing.

Finally, international forums such as the ITU, COPUOS, and UNOOSA can reinforce these efforts by endorsing high-level norms, but effective governance will ultimately emerge through implementation. By anchoring global coordination in open standards and operational systems, rather than in centralized authority, the US can catalyze a federated SSA/STC ecosystem that achieves global conformity, resilience, and long-term sustainability.

CONCLUSION

The need for a robust and comprehensive approach to SSA/STC is urgent and growing. As the United States stands at the forefront of this new space era, it has a unique opportunity to lead the way through innovative domestic policies, advanced technologies, and strategic international collaboration. By establishing clear standards and frameworks, investing in AI-driven solutions, and setting a global example in space governance, the US can mitigate the risks associated with an increasingly congested and contested orbital environment. This domestic and international effort will not only enhance the safety and security of space operations but also secure America's position as a responsible steward of the orbital commons. Immediate action is essential; proactive measures will ensure the long-term sustainability of space, enabling a vibrant ecosystem in which both commercial ventures and scientific exploration can thrive.

LIST OF ABBREVIATIONS

4S	Space security, safety, and sustainability
ADR	Active debris removal
AI	Artificial intelligence
API	Application programming interface
COPUOS	UN Committee on Peaceful Uses of Outer Space
DOD	Department of Defense
FCC	Federal Communications Commission
GEO	Geostationary orbit
GLONASS	Global Navigation Satellite System (Russian Federation)
GNSS	Global navigation satellite system
GPS	Global Positioning System
ICAO	International Civil Aviation Organization
ICG	International Committee on GNSS
IGS	International GNSS Service
ITU	International Telecommunication Union
LEO	Low Earth orbit
ML	Machine learning
NASA	National Aeronautics and Space Administration
OSC	Office of Space Commerce
RINEX	Receiver Independent Exchange Format
SSA	Space situational awareness
STC	Space traffic coordination
TraCSS	Traffic Coordination System for Space
UNOOSA	United Nations Office for Outer Space Affairs

NOTES

1. Simone D’Amico, Tycho Bogdanowitsch, and Rebecca Wang, “Space Safety and Sustainability, Part I: Past and Present Practices,” Hoover Institution, Technology Policy Accelerator, September 2025.

2. See D’Amico et al., “Space Safety,” 13–18 (“International Policy”).

3. See D’Amico et al., “Space Safety,” 26–31 (“Looking Up and Toward the Future”).

4. See D’Amico et al., “Space Safety,” 19–22 (“Domestic Policy”).

5. See D’Amico et al., “Space Safety,” 6–13 (“Operating in Space”).

6. American Institute of Aeronautics and Astronautics (AIAA), “AIAA, Iridium, OneWeb, SpaceX Release ‘Satellite Orbital Safety Best Practices’ Reference Guide,” updated May 15, 2026, https://aiaa.org/2026/05/18/aiaa-amazon-leo-eutelsat-iridium-and-spacex-release-reference-guide-satellite-orbital-safety-best-practices-3-0/.

7. See D’Amico et al., “Space Safety,” 13–18 (“International Policy”).

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Preferred citation: Simone D'Amico, Tycho Bogdanowitsch, Walter J. Manuel, Yuji Takubo, and Rebecca Wang, "Space Safety and Sustainability, Part II: Recommendations," Technology Policy Accelerator, Hoover Institution, June 2026.

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The Leadership for Responsible Space Policy Initiative

This essay is a product of the Leadership for Responsible Space Policy Initiative, which is housed within the Hoover Institution's Technology Policy Accelerator. The initiative explores new technologies and policy frameworks that could help ensure responsible stewardship of this global commons.

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