

Governing Orbits:

Collision Prevention and Liability in the Age of Autonomous Space Operations



Winter/Spring 2026

Stanford Law School
559 Nathan Abbot Way
Stanford, CA
law.stanford.edu/policy-lab/

Policy Lab Client

Copyright 2026 by the Leland Stanford Junior University Board of Trustees



GOVERNING ORBITS

Collision Prevention and Liability in the Age of Autonomous Space Operations

Date of Publication: September 14, 2026

Table of Contents

<i>About the Space Law & Policy Lab.....</i>	<i>1</i>
<i>Acknowledgements.....</i>	<i>2</i>
<i>List of Abbreviations.....</i>	<i>4</i>
<i>Editorial Note on the FCC’s Part 100 Rules.....</i>	<i>5</i>
<i>Executive Summary.....</i>	<i>6</i>
<i>Introduction.....</i>	<i>11</i>
<i>Problem Framing.....</i>	<i>11</i>
<i>Report Roadmap.....</i>	<i>12</i>
<i>Interactions of Active Spacecraft in Space.....</i>	<i>12</i>
<i>U.S. Regulatory Landscape.....</i>	<i>14</i>
Regulatory Challenges.....	15
<i>Analytical Lenses.....</i>	<i>16</i>
Governance Spectrum.....	16
Hard Law.....	16
Industry Standards.....	18
Self-Governance.....	18
Underlying Government Infrastructure.....	19
Regulation & Innovation.....	20
Proactive vs. Reactive Policymaking.....	20
Prevention & Liability.....	21
Autonomy.....	21
<i>A. Intentional Interactions.....</i>	<i>23</i>
Introduction.....	23
Commonly Applicable Governance Regimes.....	23
Hard Law.....	23
Industry Standard.....	24
Self-Governance.....	24
Common Governance Gaps.....	25
Fragmented Institutional Authority & Lack of Mission Specific Authorization.....	25
Liability.....	26
Autonomy.....	27
(1) Intentional U.S. Private Spacecraft ↔ Spacecraft Interactions.....	28
Illustrative Scenario.....	28

Specific Governance Gaps.....	28
Analysis: Formalization and Innovation–Regulation Trade-off.....	30
(2) Intentional U.S. Private Spacecraft ↔ Registered Inactive Spacecraft.....	31
Illustrative Scenario.....	31
Specific Governance Instruments.....	32
Specific Governance Gaps.....	34
Autonomy.....	36
Analysis: Formalization and Innovation–Regulation Trade-off.....	36
(3) Intentional U.S. Private Spacecraft ↔ Space Object.....	37
Illustrative Scenario.....	37
Technological Feasibility Assessment.....	38
Specific Governance Instruments.....	38
Specific Governance Gaps.....	38
Autonomy and AI-Enabled Operations.....	39
Analysis: Formalization and Innovation–Regulation Trade-off.....	40
Policy Options.....	40
1. Authorization & Licensing of Intentional Interactions.....	40
2. Formulation of a Domestic Active Debris Removal Policy.....	42
Table 1. Proposed Measures for Intentional Interactions.....	44
<i>B. Unintentional Interactions.....</i>	45
Introduction.....	45
Commonly Applicable Governance Regimes.....	45
Hard Law.....	45
Industry Standard.....	46
Self-Governance.....	48
Common Governance Gaps.....	48
Hard Law.....	48
Industry Standard.....	50
Self-Governance.....	51
Government Infrastructure.....	51
(1) Unintentional U.S. Private Spacecraft ↔ Spacecraft Interactions.....	52
Illustrative Scenario.....	53
Specific Governance Instruments.....	53
Specific Governance Gaps.....	54
Analysis: Formalization and Innovation–Regulation Trade-off.....	56
(2) Unintentional U.S. Private Spacecraft ↔ Inactive Spacecraft & Trackable Space Objects....	57
Illustrative Scenario.....	58
Specific Governance Instruments.....	59
Specific Governance Gaps.....	59

Analysis: Formalization and Innovation–Regulation Trade-off.....	60
(3) Unintentional U.S. Private Spacecraft ↔ Untrackable Space Objects.....	60
Illustrative Scenario:.....	61
Specific Governance Instruments.....	61
Specific Governance Gaps.....	62
Analysis: Formalization and Innovation–Regulation Trade-off.....	63
Policy Options.....	64
1. Enhance Space Situational Awareness and Transparency.....	64
2. Accountability and Enforcement.....	66
3. Structural Reforms for Orbital Governance.....	67
4. Monitoring the Risk Profile of Interactions with Untrackable Space Objects.....	68
Table 2. Proposed Measures for Unintentional Interactions.....	69
Conclusion.....	71
Appendix.....	72
Domestic Tort Law and Commercial Space Activities.....	72
Domestic Tort Law May Be the Default.....	73
Procedural Issues, Insights, and Gaps.....	74
Tort Law for On-Orbit Operations: Practical Applications and Evidentiary Gaps.....	75

About the Space Law & Policy Lab

The [Stanford Space Law & Policy Lab \('25-'26, Law 810G / AA 262\)](#) was initiated by the Stanford Space Law Society and developed in partnership with the Aerospace Corporation and Stanford Law School. A graduate policy practicum, the course brings together students from law, aeronautics and astronautics, international policy, and business. The course is the first jointly listed policy lab course between Stanford Law School, the Aeronautics and Astronautics Department, and the Master's in International Policy program. This report is the main output of the Lab, which is the culmination of our team's diligent work for nearly half a year. During the Lab, we engaged and consulted with various industry stakeholders, including private space companies, senior policy officials, government entities, academic institutions, and researchers (acknowledged below) to produce this report.

Instructors

Erik Jensen, Director of the Rule of Law Program
Dinsha Mistree, Hoover Institution Research Fellow

Teaching Assistant

Cody Wang Chenxi, J.D. (Class of 2027)

Authors (in alphabetical order of last name)

Cody Wang Chenxi, J.D. (Class of 2027, President of the Stanford Space Law Society)
Somi Eigbe, M.S. Aeronautics and Astronautics (Class of 2027)
Kazumi Hoshino-Macdonald, J.D., Ph.D. Candidate Political Science
Grace Ra Kim, Ph.D. Candidate Aeronautics and Astronautics
Laurel Kim J.D., M.A. Public Policy (Class of 2026)
Argyris Kriezis, Ph.D. Candidate Aeronautics and Astronautics
Paulina Montgomery, M.A. International Policy (Class of 2027)
Emma Nicolai, M.S. Aeronautics and Astronautics (Class of 2027)
Vale Rasmussen, B.S. Aeronautical and Astronautical Engineering (Class of 2026)
Matt Rogowski, J.D. (Class of 2026)

Haas Community Engaged Learning Coordinator

Anika Leigh Turcotte, B.S. Management Science & Engineering (Class of 2028)

Acknowledgements

This report is the product of a highly iterative process with our policy lab client, Aerospace Corporation. That process was crucial in shaping the report. The Aerospace Corporation team consisted of Pamela Wood, Senior Project Leader, Vehicle Autonomy and System Trust Department; Kerianne Hobbs, Senior Engineering Specialist, Vehicle Autonomy & System Trust; Michael Gleason, Senior Project Engineer, Center for Space Policy and Strategy; and Katherine Melbourne, Policy Analyst, Center for Space Policy and Strategy. Special thanks to Katherine Melbourne who was our principal contact and generously provided perspective throughout.

The report benefited enormously from lectures and interaction with a first-rate group of experts including: David Goldstein, Principal Guidance Navigation and Control Engineer at SpaceX; Bhavya Lal, Professor of Policy Analysis at the RAND School of Public Policy, former NASA Associate Administrator for Technology, Policy, and Strategy; Diane Howard, Adjunct Professor at McGill University Institute of Air & Space Law; Major General Steven J. Butow, Military Deputy for the Defense Innovation Unit; Omar Pimentel, then Policy and Strategy Lead for the Defense Innovation Unit's Space Portfolio and now Director of Frontier Strategy at Type One Ventures; Professor Stefan-Michael Wedenig, Executive Director of the Institute and Centre for Research in Air and Space Law, McGill University; Christopher Kunstadter, President of Triton Space LLC, former Global Head of Space at AXA XL; Caryn Schenewerk, Chief Policy Officer at Vast; and Tuana Yazici, Team leader of the International Institute of Space Law Working Group on Legal Aspects of AI in Space.

Stanford team members interviewed experts who further informed the report including Araz Feyzi, Co-Founder & Chief Technology Officer of Kayhan Space; Dan Berkenstock, Distinguished Research Fellow, Hoover Institution; Sandra Magnus, Former Astronaut, formerly Chief Engineer at the Traffic Coordination System for Space and currently Principal at AstroPlanet and Professor of the Practice at Georgia Tech; Stephen Kitay, Senior Vice President, Space Defense at True Anomaly; Richard DalBello, former Director, Office of Space Commerce and currently Principal of RDB Space; Andrew Bonwick, Vice President for Product Development, RELM Insurance; and Walter Manuel, PhD Candidate and member of Stanford's Space Rendezvous Laboratory.

Luciana Herman, Program Director for the Stanford Law & Policy Lab, provided support throughout. Shoshanah Cohen, Director of Community Engaged Learning for Engineering at the Haas Center for Public Service, and Jenny Scholes, Student Services Administrator, Department of Aeronautics & Astronautics helped coordinate this jointly listed policy lab. Alexis Opferman, a Master of Business Administration candidate, actively participated in the Winter quarter class. Following the substantive drafting in June 2026, Cody Wang Chenxi, Grace Ra Kim, Paulina Montgomery, and Anika Leigh Turcotte formed an editorial team that revised and finalized the report, including updating it to reflect regulatory developments through August 2026.

Finally, it is impossible to adequately acknowledge the incredible initiative, thoughtfulness, productivity and commitment of Chenxi “Cody” Wang to every aspect of this policy lab.

Erik Jensen
Director of the Rule of Law Program
Stanford Law School

List of Abbreviations

Abbreviation	Definition
18 SDS	18th Space Defense Squadron
ADR	Active Debris Removal
AI	Artificial Intelligence
AIAA	American Institute of Aeronautics and Astronautics
API	Application Programming Interface
CAM	Collision Avoidance Maneuver
CARA	Conjunction Assessment Risk Analysis
CDM	Conjunction Data Message
CSLA	Commercial Space Launch Act
COLREGS	Convention on the International Regulations for Preventing Collisions at Sea
CONFERS	Consortium for Execution of Rendezvous and Servicing Operations
DAS	Debris Assessment Software
DoC	Department of Commerce
DoD	Department of Defense
FAA	Federal Aviation Administration
FCC	Federal Communications Commission
GEO	Geostationary Earth Orbit
GNC	Guidance, Navigation, and Control
IADC	Inter-Agency Space Debris Coordination Committee
INTELSAT	International Telecommunications Satellite Organization
ISAM	In-Space Servicing, Assembly, and Manufacturing
ISO	International Organization for Standardization
LEO	Low Earth Orbit
NASA	National Aeronautics and Space Administration
O/O	Owner/Operator
ODMSP	Orbital Debris Mitigation Standard Practices
OSC	Office of Space Commerce
Pc	Probability of Collision
RPO	Rendezvous and Proximity Operations
RPOD	Rendezvous, Proximity Operations, and Docking
SSA	Space Situational Awareness
SSN	Space Surveillance Network
STC	Space Traffic Coordination
TraCSS	Traffic Coordination System for Space
USSF	United States Space Force
VTSS	Variable Trajectory Space Station system

Editorial Note on the FCC’s Part 100 Rules

On July 22, 2026, after the research and drafting for this report were substantially complete, the Federal Communications Commission (“FCC”) adopted “Space Modernization for the 21st Century,” a Report and Order and Further Notice of Proposed Rulemaking (the “Order”). Among other changes, the Order replaces Part 25 of the FCC rules with a new Part 100, establishes a Variable Trajectory Space Station licensing pathway, and adopts ephemeris-sharing, collision avoidance, and rendezvous and proximity operations requirements. As of the time of publication, the new Part 100 has yet to come into force. The Order is one of a number of ongoing regulatory developments discussed throughout this report. Following the announcement of the Order, this report has been updated to reflect certain aspects of these developments. The stakeholder engagement informing this report was conducted before the Order’s release and does not necessarily reflect industry views on the adopted rules.

Executive Summary

The governance of near-Earth orbit increasingly depends not only on formal government regulations, but on standards and practices developed by commercial companies and operators. The dramatic decrease in launch costs over the past decade has opened orbital access to an increasingly diverse set of actors. However, older governance frameworks were not designed for this proliferation in orbital activity. In the absence of formal rules, industry-led norms continue to form through informal standards, multilateral commercial agreements, or internal company practices. These norms are on track to form the foundational rules-of-the-road for future orbital activity. And once these rules are hardened, retrofitting formal regulation becomes both practically and politically challenging. This report addresses this critical window. In particular, we identify policy options for the commercial space industry to help ensure that the fundamental principles governing orbital activity are established with intention and careful deliberation.

The rapid transformation of Earth's orbital environment heightens the urgency of this governance challenge. Private companies are transforming the once state-dominated outer space domain into an increasingly crowded commercial ecosystem. Over the past five years, the annual number of objects launched into space has more than tripled.¹ In 2024, around 10,000 satellites orbited the Earth, and this number could grow nearly tenfold by 2030.² Nearly 60% of all objects ever launched into space were launched in the past five years.³ Once in orbit, space objects must navigate a sprawling web of over 140 million pieces of space debris, all of which are moving at hypervelocity several times faster than a bullet.⁴ This rapid expansion raises concerns about the risk of a cascading collision chain, commonly known as the Kessler Syndrome.⁵

At the same time, commercial space operations are becoming increasingly complex. “Traditional” space activities centered around telecommunications, remote sensing, and rocket launches. Today, “novel” space activities strive to run the gamut of once-futuristic visions, from mega-constellation swarms of micro-satellites, spacecraft repair and refueling, and orbital debris removal, to pharmaceutical manufacture in space, private space stations, off-Earth hotels, and more.⁶

Amidst these developments, the appropriate role of regulatory governance remains contested. Observers frame regulation in a seemingly paradoxical manner where it is criticized as

¹ Our World in Data, “Annual Number of Objects Launched into Space,” accessed August 1, 2026, <https://archive.ourworldindata.org/20260730-021957/grapher/yearly-number-of-objects-launched-into-outer-space.html>.

² European Space Agency, “Around 100,000 Satellites Are Expected to Be in Orbit by 2030,” April 1, 2025, https://www.esa.int/ESA_Multimedia/Images/2025/04/Around_100_000_satellites_are_expected_to_be_in_orbit_by_2030.

³ Our World in Data, “Cumulative Number of Objects Launched into Space,” accessed August 1, 2026, <https://ourworldindata.org/grapher/cumulative-number-of-objects-launched-into-outer-space>.

⁴ European Space Agency, “Space Environment Statistics,” ESA Space Debris User Portal, July 31, 2026, <https://sdup.esoc.esa.int/discosweb/statistics/>.

⁵ Margo Anderson, “Have We Reached a Space-Junk Tipping Point?,” IEEE Spectrum, September 30, 2025, <https://spectrum.ieee.org/kessler-syndrome-space-debris>.

⁶ Belfer Center for Science and International Affairs, “Explainer: Novel Space Activities in the Executive Order on Enabling Competition in the Commercial Space Industry,” September 15, 2025, <https://www.belfercenter.org/research-analysis/explainer-novel-space-activities-executive-order-enabling-competition-commercial>.

lagging behind technology while also threatening to stifle innovation. Regulation appears both archaically insufficient and overbearingly harsh. Therefore, policy leaders must confront a series of new questions. What should be done about overcrowding orbits? Should we focus on matters that only allow prevention rather than direct liability and intervention? What is the correct approach towards “novel space activities”? Should modern space governance frameworks be enhanced to better govern and enable these activities?

This report addresses these questions by (i) clarifying the key governance challenge surrounding “novel space activities,” (ii) evaluating the extent to which existing space governance frameworks apply to these activities, and (iii) discussing policy options moving forward.

The core governance challenge in the “New Space Era” is the combined effect of two primary drivers: (i) the rapid growth in the number of orbital objects and (ii) more intentional interaction between these objects. These “intentional interactions,” referring to planned proximity operations such as on-orbit servicing, active debris removal, and in-space assembly, add new operational complexity to an already crowded environment. If mismanaged, the combination of greater congestion and a more complex orbital environment could significantly increase the risk of more collisions. Added to this mix is a third, complicating driver: (iii) the growing integration of autonomous and AI decision-making capabilities into orbital operations. Given the scale of existing and proposed constellations, together with the growing communications delays associated with deep space missions that travel farther away from Earth, increasing reliance on autonomous capabilities will become unavoidable. As software and AI systems buttress or even substitute for human decision-making, this presents additional considerations for policy leaders.

To structure this analysis, we introduce a taxonomy for commercial space activities. This framework categorizes (a) human-made objects in space as “spacecraft” and “space objects” and (b) the orbital activities between them. “Spacecraft” are objects designed and launched for independent operations in space. “Space objects” are non-functional human-made objects in orbit. Orbital activities are understood as *physical interactions* between human-made objects in space, i.e., situations where one object comes into proximity with another. In the “traditional space activities” era, orbital interactions were mostly “unintentional,” or simply unplanned conjunctions. In the “novel space activities” era, technological advances have enabled a range of “intentional interactions,” where a spacecraft purposefully approaches and interacts with other objects in space. The taxonomy maps onto the following three-by-two matrix:

	Intentional Interaction	Unintentional Interaction
Active Spacecraft - Active Spacecraft	E.g., Rendezvous proximity and docking operations between two active spacecraft	E.g., Unplanned conjunction between two maneuverable spacecraft
Active Spacecraft - Inactive Spacecraft	E.g., On-orbit servicing, active spacecraft repairs another non-maneuverable spacecraft	E.g., Conjunction between a maneuverable and a non-maneuverable spacecraft

Active Spacecraft - Space Object	E.g., Active Debris Removal of an unattributed space object (debris)	E.g., Conjunction between an operational spacecraft and space object (debris)
---	--	---

The report focuses on the United States (“U.S.”) domestic legal framework for civil space activities. The most commercially consequential space operators are American, and day-to-day orbital operations are governed through national regimes, rather than international frameworks. Moreover, rather than limiting our analysis to “hard law,” i.e., binding legal instruments such as treaties, statutes, and government regulations, we conceptualize governance as a continuum that spans hard law, industry standards, and self-governance (or self-regulation).⁷ We also account for the underlying technological infrastructures that enable governance in the first place. This governance landscape is actively developing. In July 2026, the Federal Communications Commission (“FCC”) adopted the new Part 100 rules, transforming several previously voluntary operational practices into binding license conditions.⁸ Other developments, including the pending ORBITS Act in Congress and the ongoing deployment of the Space-Track and Traffic Coordination System for Space (“TraCSS”) are also underway.

Our analysis identifies six major gaps in existing U.S. governance instruments:

1. Absence of binding standards for the operational details of spacecraft coordination and collision avoidance
2. Fragmented institutional authority and the lack of mission specific authorization pathways
3. Inability of the liability regime to clearly attribute fault if collisions occur, especially when autonomous systems are involved
4. Lack of regulatory guidance or industry standards that could guide the development and deployment of autonomous systems
5. Shortcomings in existing and proposed public space situational awareness infrastructure such as TraCSS
6. Lack of a structured plan for the removal of key pieces of debris that pose the highest risks to the orbital environment

These findings draw on the Policy Lab’s engagement with satellite operators, regulators, insurers, and technical experts over two academic quarters. Accordingly, we propose the following policy options.

⁷ Daniel E. Walters and Hannah J. Wiseman, “Self-Regulation in Emerging and Innovative Industries,” *Houston Law Review* 62, no. 3 (2025): 543.

⁸ See Federal Communications Commission, Space Modernization for the 21st Century Report and Order and Further Notice of Proposed Rulemaking, SB Docket No. 25-306 (July 22, 2026), <https://docs.fcc.gov/public/attachments/FCC-26-47A1.pdf> [hereinafter FCC 2026 Order].

Proposals for Intentional Interactions

Intentional interactions are planned orbital activities, such as rendezvous, proximity operations, and docking (“RPOD”), assembly and manufacturing, and active debris removal (“ADR”). The proposals below respond to the governance issues of pre-mission authorizations, coordination, and the allocation of liability when interactions go awry.

Intentional Proposals	
Group 1: Authorization & Licensing of Intentional Interactions	
1.1 Establish a risk-tiered authorization and coordination framework for rendezvous and proximity operations	Create a risk-tiered framework in which coordination, consent, and authorization obligations escalate as spacecraft approach one another
1.2 Mandatory pre-approach notification requirement as a licensing condition	Condition licenses on advance notice to approach another operator
1.3 Mission-specific financial responsibility for on-orbit servicing	Require financial assurance for servicing missions in relation to mission risk
Group 2: Domestic Active Debris Removal Policy	
2.1 Formulate a risk-based debris removal target list	Categorize and prioritize the removal of space objects that pose the greatest environmental risk
2.2 Standardized consent and ownership templates for ADR	Create model instruments for consent to remove another operator’s space object
2.3 Adopting the proposed ORBITS Act	Establish a statutory basis for orbital debris removal

Proposals for Unintentional Interactions

Unintentional interactions are unplanned conjunctions between spacecraft and inactive objects, including debris. The proposals below respond to the enhancement of information sharing, alignment of incentives, and, similar to the intentional interaction proposal, the allocation of liability.

Unintentional Proposals	
Group 1: Enhance Space Situational Awareness and Transparency	
1.1 Ensure access to 24/7 collision avoidance contacts through Space-Track and TraCSS	Verify designated contact points, log attempted communications, and provide regulators with a compliance record
1.2 Promote additional industry standard resources on Space-Track and TraCSS	Provide industry best practices through platforms used by operators

1.3 Establish minimum ephemeris and autonomy reporting standards	Prescribe a mandatory ephemeris reporting cadence and require disclosure of autonomous maneuver criteria
1.4 Create a “Good Standing” score on TraCSS for orbital operators	Encourage operator behavior through reputational and commercial incentives
Group 2: Accountability and Enforcement	
2.1 Increase penalties for debris generation	Raise the cost of debris-generating conduct to match the environmental harm caused
2.2 Establish a rebuttable “Presumption of Liability” standard for sub-standard operators	Shift the burden of proof when fault cannot be or is difficult to establish in orbit
Group 3: Structural Reforms for Orbital Governance	
3.1 Establish a statutory On-Orbit Authorization Regime	Consolidate fragmented oversight regimes under the same jurisdictional roof
3.2 Establish and enforce standards for domestic “Right-of-Way” protocols	Specify rules for spacecraft in near conjunction situations to enable coordination even when real-time communication is absent

Collectively, these proposals build upon the existing institutional mechanisms that govern orbital operations in outer space. They specify what action(s) needs to be done, who needs to act, and what happens when an operator fails to meet its obligations. Across the board, autonomy functions as a complicating condition. Operators currently rely, and will likely increasingly rely, on autonomy as a tool for orbital maneuvers and inter-spacecraft coordination. Nonetheless, the exact allocation of responsibility and liability of autonomously made decisions remains an open question. Above all, as orbital activity accelerates in the coming years and early operational practices gradually settle into norms, the window for shaping these arrangements is narrowing. The time to act is now.

Introduction

Outer space continues to scale rapidly and grow in complexity. The space domain has entered a new operational era defined by both the escalating number of objects in orbit, and the increasing complexity in how these objects interact with one another. Commercial actors significantly influence this era by launching large satellite constellations at scale. The implementation of new technologies and novel space activities such as on-orbit servicing, debris removal, and proximity operations transforms space from a passive domain into one characterized by frequent and intentional interactions between spacecraft. At the same time, advances in automation and artificial intelligence (“AI”) enable spacecraft to make autonomous decisions about navigation, collision avoidance, and mission execution with limited or no human intervention.

Undoubtedly, the convergence of intentionality, scale, and autonomy introduces a qualitatively new risk environment that historical space governance frameworks remain ill-equipped to address. The foundational treaties and agreements were designed for a domain dominated by a small number of state actors, where interactions between spacecraft were rare and, at most, unintentional.⁹¹⁰ They were intended to address discrete incidents involving clearly identifiable actors within clear causal chains. However, the modern orbital environment is markedly different. Commercial operators deliberately maneuver spacecraft into close proximity and operate in congested orbital regimes.

On-orbit collisions, or unintended interactions, can generate cascading effects including degradation or loss of critical systems, debris creation, and instability within the orbital regime. These shifts towards an increasing reliance on autonomous systems also raise new questions about the standards of decision-making and the attribution of responsibility in the case of accidents.

In this context, policy thinkers need to consider how to manage these risks while ensuring policy frameworks can effectively oversee and adapt to a dynamic domain with complex interactions.

Problem Framing

The current discourse on space governance typically revolves around the growing risk of collisions due to orbital congestion. While this framing remains important, it is not entirely sufficient. A more precise and policy relevant framing centers on two primary drivers:

- (i) **Increasing number of objects in orbit**, generated by commercial mega-constellations and decreased launch costs.

⁹ Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies, Jan. 27, 1967, 18 U.S.T. 2410, 610 U.N.T.S. 205 [hereinafter Outer Space Treaty].

¹⁰ Convention on International Liability for Damage Caused by Space Objects, Mar. 29, 1972, 24 U.S.T. 2389, 861 U.N.T.S. 187 [hereinafter Liability Convention].

- (ii) **More intentional interactions**, including servicing missions, debris removal, and proximity operations.

In addition, we also take into account one complicating condition:

- (iii) **The integration of autonomy and AI in these interactions**, enabling spacecraft to make independent operational decisions.

Based on this framework, this report examines how these governance challenges manifest across different types of interactions between space objects. By analyzing both intentional and unintentional interactions across spacecraft, non-maneuverable space objects, and debris, the paper identifies specific gaps in existing legal and policy frameworks and evaluates potential pathways for reform.

While space governance is often discussed through the lens of international law, this report focuses primarily on domestic legal and regulatory frameworks within the U.S. This reflects both practical and analytical considerations, including the fact that many of the most consequential actors in the modern space domain are U.S.-based private companies, and their activities are principally governed through national licensing, oversight, and compliance regimes. Moreover, as space operations become more autonomous and commercially driven, real-time decisions about authorization, supervision, and risk management need to be made through domestic policy. Accordingly, this report emphasizes how U.S. law and policy can evolve to address emerging challenges in oversight and liability, while acknowledging that domestic governance frameworks emerge from a broader international legal backdrop.

Report Roadmap

First, we introduce the analytical framework of the report. Second, the report evaluates the six intentional and unintentional orbital interactions. Finally, the report concludes with potential policy recommendations and proposals for near-, medium-, and long-term implementation aimed at strengthening governance, collision prevention, and liability frameworks for increasingly autonomous space activities. A conclusion and supporting material remain at the end of the report.

Interactions of Active Spacecraft in Space

To identify gaps in existing legal frameworks governing on-orbit operations, we begin by conceptualizing the types of “on-orbit interactions” that active spacecraft may encounter. By “interactions,” we mean situations where spacecraft come into close proximity with another space object. Historically, most interactions were “unintentional,” i.e., unplanned conjunctions. In recent years, however, technological advances have enabled a growing range of “intentional interactions,” i.e., spacecraft that purposefully interact with other space objects. This includes on-orbit monitoring, servicing, and removal.

This report adopts the following definitions for the purposes of our discussion. “Spacecraft” describes any human-made object designed and launched for independent operations in space, whether or not it currently has operational capabilities. “Active spacecraft” refers to objects that retain the capability to control their motion and respond to commands. “Inactive spacecraft” refers to human-made objects that were either launched without control capabilities or those that can no longer be controlled by their operators but could regain functionality through repairs/service. “Space objects” encompasses non-functional human-made objects in orbit without the possibility of regaining independent operational capabilities.

Across both “intentional” and “unintentional” categories, the nature of an interaction depends on the status of the objects involved. The simplest case is interaction between two active spacecraft, where both operators retain control and can either coordinate intentional activities or take action to avoid accidental encounters. Greater complexity arises when one or more objects are inactive. In such cases, there needs to be a distinction between spacecraft and space objects that remain attributable to a launching state and those that exist either naturally or as a result of collisions or breakups. Although multiple classification approaches exist, a clear and practical distinction can be drawn by categorizing objects as registered or unregistered under the Convention on Registration of Objects Launched into Outer Space (“Registration Convention”).¹¹

Registration, however, should not be conflated with trackability. Registration establishes a legal record of a space object and its launching State, whereas trackability refers to the technical ability to detect, identify, and continuously monitor an object’s location using space surveillance capabilities. While registered objects are generally more readily identifiable because they are associated with publicly available registration and orbital information, their real-time trackability ultimately depends on factors such as object size, orbital regime, and the capabilities of existing space surveillance networks. Consequently, the degree of trackability varies across the interaction categories discussed below.

An interactive version of this taxonomy is available at: <https://orbital-interactions.netlify.app/>.

Interaction Categories	Intentional	Unintentional
Active Spacecraft ⇔ Active Spacecraft	Planned proximity operations between two active spacecraft such as on-orbit inspection, rendezvous, and docking.	Unplanned orbital conjunction between two active spacecraft.
Active Spacecraft ⇔ Registered Inactive Spacecraft or Space Object	Planned proximity operations between an active spacecraft and an inactive spacecraft or space object registered by a nation.	Unplanned orbital conjunction between an active spacecraft and an inactive spacecraft or space object registered by a nation.

¹¹ Convention on Registration of Objects Launched into Outer Space art. II, Jan. 14, 1975, 28 U.S.T. 695, 1023 U.N.T.S. 15 [hereinafter Registration Convention].

Active Spacecraft ⇔ Unregistered Space Object	Planned proximity operations between an active spacecraft and an unregistered space object.	Unplanned orbital conjunction between an active spacecraft and an unregistered space object.
--	--	---

Note 1: Trackability varies across interaction types. Intentional interactions involve only routinely trackable objects (approximately 10 cm or larger in characteristic size in Low Earth Orbit (“LEO”)), consistent with current space surveillance networks.¹² Unintentional interactions are more complex: (i) active to active spacecraft are both generally identifiable and trackable, (ii) active spacecraft to inactive space objects may not always be trackable due to unattributability to an existing state actor, (iii) active-space debris objects may not be trackable if the debris is below the detection threshold.

Note 2: Spacecraft registration is according to the “United Nations Register of Objects Launched into Outer Space” catalogue. Governmental stealth activities on orbit, which may involve trackable but unregistered space objects, are beyond the scope of this report.

Note 3: This report does not address interactions between two inactive spacecraft or space objects. As neither party retains control capabilities, such interactions fall outside the governance frameworks discussed in this report.

U.S. Regulatory Landscape

The U.S. operates within a broader international legal framework established under four core United Nations space treaties. These include the 1967 Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space (“Outer Space Treaty”), the 1968 Agreement on the Rescue of Astronauts (“Rescue Agreement”), the 1972 Convention on International Liability for Damage Caused by Space Objects (“Liability Convention”), and the Registration Convention.¹³ Together, these treaties establish the foundational principles governing state conduct in outer space, consisting of international responsibility for national space activities, liability for damage caused by space objects, and jurisdiction over registered objects in orbit. Most importantly, Article VI of the Outer Space Treaty requires signatory states to provide “authorization and continuing supervision” of both governmental and non-governmental space activities.¹⁴ This establishes an affirmative obligation for states to oversee private actors operating under their jurisdiction. Accordingly, the modern U.S. regulatory framework, including licensing, debris mitigation, and operational oversight regimes exists in large part as a domestic manifestation of these international obligations.

¹² Mark Matney et al., The NASA Orbital Debris Engineering Model 3.1: Development, Verification, and Validation, JSC-E-DAA-TN73945, paper presented at the International Orbital Debris Conference, Sugar Land, TX, December 9–12, 2019, National Aeronautics and Space Administration, <https://ntrs.nasa.gov/citations/20190033490>

¹³ Liability Convention, art. VII.

¹⁴ Outer Space Treaty; Agreement on the Rescue of Astronauts, the Return of Astronauts and the Return of Objects Launched into Outer Space, Apr. 22, 1968, 19 U.S.T. 7570, 672 U.N.T.S. 119; Liability Convention; Registration Convention.

The U.S. authority over space activities is distributed across multiple government bodies. The Federal Aviation Administration (“FAA”) regulates launch, reentry, payload review, and some debris-mitigation issues.¹⁵ FCC regulates spectrum access and imposes orbital-debris conditions.¹⁶ The Department of Commerce (“DoC”) is moving toward a broader certification process for novel space activities.¹⁷ The National Oceanic and Atmospheric Administration licenses commercial remote sensing.¹⁸ The Department of State, Department of Defense (“DoD”), and National Aeronautics and Space Administration (“NASA”) are responsible for export control compliance, national-security review, and mission-coordination support, respectively.

Regulatory Challenges

A central challenge in regulating space activities stems from the mismatch between regulatory timelines and technological development cycles. Spacecraft require years to design and build. Yet, once deployed, they are difficult or impossible to modify, and are often exempt from newly introduced regulations. This requires policymakers to attempt to anticipate future technological and operational conditions well in advance, thus increasing the risk that regulations become outdated or misaligned with evolving industry realities. At the same time, the diversity of spacecraft missions, ranging from low-altitude, non-maneuverable Earth observation systems to highly maneuverable communications systems, makes it difficult to design uniform rules. As a result, regulators often rely on flexible, performance-based approaches rather than prescriptive requirements. While this flexibility supports innovation, it can also create ambiguity in how compliance is evaluated, particularly when operators must demonstrate reliability or risk mitigation without standardized methodologies. In practice, however, regulation often evolves *in response to* rather than *in anticipation of* technological innovation. For example, the FCC’s orbital debris policy evolved alongside major advances in space operations, such as the emergence of mega-constellations.¹⁹

More broadly, the lack of well-defined frameworks for liability, coordination, and dispute resolution increases both operational and financial uncertainty for companies. Rather than simply reflecting a lack of constraints, this ambiguity can discourage investment and hinder innovation by making it difficult for operators to plan, design, and execute missions with confidence. Other challenges include unequal industry participation in regulatory development (where smaller firms often lack the resources to influence standards-setting processes) as well as the absence of clear evaluation criteria for certain requirements, such as post-mission disposal reliability.

¹⁵ 14 C.F.R. pts. 415, 417, 431, 435, 450 (2026).

¹⁶ 47 C.F.R. pt. 25 (2026) (to be replaced by 47 C.F.R. pt. 100 upon its effective date).

¹⁷ U.S. Department of Commerce Office of Space Commerce, “Space Commerce Certification,” accessed August 1, 2026, <https://space.commerce.gov/space-commerce-certification/>.

¹⁸ 15 C.F.R. pt. 960 (2026).

¹⁹ See Mitigation of Orbital Debris in the New Space Age, 85 Fed. Reg. 52422 (Aug. 25, 2020) (codified at 47 C.F.R. § 25.114).

Analytical Lenses

Governance Spectrum

This report adopts a three-tier continuum including hard-law, industry standards, and self-governance. It also examines existing government infrastructure, which serves as an underlying foundation for regulation and coordination although not formally part of the governance spectrum. These governance instruments differ in who formulates the rules, their legal bindingness, and enforcement. Understanding the governance spectrum illustrates how governance in practice cuts across multiple tiers, as no single tier will be sufficient to govern on its own. In novel policy arenas such as space, this opens up possibilities for diverse forms of governance.

Hard Law

Hard law refers to legally binding rules created by governments or international agreements including statutes, regulations, or treaties. Typically, these rules are enforceable through formal mechanisms such as courts, fines, or sanctions, and noncompliance carries clear legal consequences. In the space domain, hard law includes the international treaties such as the Outer Space Treaty and the Liability Convention. Domestic hard law includes export controls and satellite licensing regimes as they are mandatory and backed by state authority. The strengths of hard law lie in its formal authority and enforceability. It establishes clear mandates, mechanisms for dispute resolution, and a basis for accountability. However, hard law is often slow to adapt to rapidly evolving technological capabilities and subject to political contestation.²⁰

Information Box: Domestic Tort Law

In the U.S. context, a particularly relevant type of hard law is domestic tort law, which will likely be the default mechanism for resolving on-orbit disputes between American commercial operators when no other body of law fills the role. Internationally, the Liability Convention specifically and exclusively covers on-orbit liability disputes *between* nation states and their respective actors.²¹ Domestically, the 2015 Commercial Space Launch Competitiveness Act covers only licensed launch activities and third-party claims, and there is no federal licensing requirement for on-orbit operations at all. That leaves domestic tort and contract law to occupy the field by default. Article VIII of the Outer Space Treaty preserves the state of registry's jurisdiction over its space objects, providing the jurisdictional foothold for American courts to hear American-only on-orbit disputes, though the proposition has never been formally adjudicated.²²

²⁰ Ramsey Haggerty, "Soft Law and Hard Law," UAB Institute for Human Rights Blog, March 26, 2026, <https://sites.uab.edu/humanrights/2026/03/26/soft-law-and-hard-law/>.

²¹ Liability Convention, art. VII.

²² Outer Space Treaty, art. VII.

An important precedent is *Martin Marietta v. INTELSAT*²³, which yields two lessons that will shape any future on-orbit case. First, courts hesitate to overlay general tort duties on contractual relationships between commercially sophisticated parties. In *Martin Marietta*, the Fourth Circuit applied Maryland’s rule that negligent misrepresentation is unavailable where the only relationship is contractual and the contract does not create an express duty of due care. Second, gross negligence cannot be contractually waived. This is a proposition reinforced by Representative Bart Gordon’s floor statements²⁴ during the 2004 Commercial Space Launch Act (“CSLA”) Amendments and codified in subsequent FAA regulations, and one that establishes a hard floor on commercial risk-allocation. The *Benavides v. Tesla, Inc.*²⁵ case in 2025 supplements *Martin Marietta* by supplying the worked gross-negligence application *Martin Marietta* declined to produce. In *Benavides*, a federal jury found gross negligence against an autonomous-system manufacturer, sustained against Tesla’s renewed post-trial motion in February 2026, with the jury using Tesla’s own marketing to define the standard of care. Together, the two cases sketch the doctrinal architecture an on-orbit plaintiff would inhabit, namely, contract claims are primary whereas tort is constrained to situations where parties are sophisticated and contractually bound, and gross negligence serves as the non-waivable backstop. This, of course, mostly applies only to parties already in privity of contract. For true third-party negligence cases, all elements of the claim will be matters of first impression for the court. This means courts will have to look at a mix of industry standards, federal regulations, and company operating procedures to create a workable standard of care.

Substantial uncertainties remain at every element of the prima facie case. To begin with, there is no settled benchmark for the standard of care for “the reasonably prudent satellite operator.” That said, industry self-regulation may supply information for courts to construct one, such as SpaceX’s January 30, 2026 FCC application referencing an “advanced, automated collision avoidance system.”²⁶ Attribution and causation are likely to be the dispositive obstacles in practice. The millions of pieces of unattributable space debris preclude defendant identification in many scenarios. Proprietary navigation and command-and-control data may never reach the courtroom. And there are no orbital equivalents to the dashcam footage and eyewitness testimony that drive terrestrial collision litigation. The growing role of AI and autonomy compounds these problems by introducing an additional layer to the analysis: software developers and component suppliers. The “black box” problem regarding AI systems means that even if a workable standard of care for orbital operations emerges, attempting to apply it to opaque AI decision-making could be futile. The remainder of this analysis works through these elements in sequence, with the procedural-jurisdictional, evidentiary, and autonomy-specific details developed at greater length in the appendix that follows this report.

²³ 991 F.2d 94 (4th Cir. 1993).

²⁴ H.R. Rep. No. 108-429, at 37 (2004).

²⁵ No. 1:21-cv-21940-BLOOM/Torres (S.D. Fla.)

²⁶ Application of Space Exploration Holdings, LLC for Authority to Launch and Operate the SpaceX Orbital Data Center System, ICFS File No. SAT-LOA-20260108-00016, at 4 (F.C.C. Jan. 30, 2026)

Industry Standards

Industry standards sit in the middle. Private or multi-stakeholder organizations, such as technical bodies or industry consortia, typically develop these standards. They can include guidelines, best practices, and technical standards. Unlike hard law, industry standards remain non-binding, though they can exert significant influence by shaping expectations and behavioral norms. However, they often become quasi-mandatory as firms adopt them to ensure interoperability, safety, and/or market access. For example, technical standards for satellite communications or debris mitigation might not be laws themselves, but companies may follow them to remain competitive or compliant with broader regulatory expectations. In some cases, governments incorporate these standards into regulation, effectively giving them legal force. Industry standards do face limitations in terms of consistency and enforcement as adoption is usually voluntary, and compliance can vary immensely across actors.²⁷

Self-Governance

Self-governance (or self-regulation) represents the least formal tier of the governance spectrum, encompassing internal company policies, operational practices, and voluntary commitments that shape behavior in the absence of binding legal requirements. These practices are not mandated by law or codified in industry standards but are driven instead by a combination of intra-actor incentives, for example, reputational concerns, ethical commitments, the need to safeguard high-value assets, and the desire to avoid stricter government intervention. Self-governance proves particularly influential in the space domain as many operational decisions, such as how aggressively to maneuver to avoid a conjunction or how to design autonomous collision avoidance systems, are instituted at the firm level. The shared nature of orbital space as a global commons further reinforces these incentives considering irresponsible behavior can degrade the environment for all operators including the originating actor.²⁸

In practice, companies have adopted practices that exceed formal regulatory requirements through self-governance strategies. For example, Iridium conducted one of the first full-constellation rapid de-orbit campaigns between 2017 and 2019, actively disposing of satellites through atmospheric re-entry despite regulatory allowances for slower disposal timelines.²⁹ Similarly, SpaceX implemented collision avoidance thresholds significantly more conservative than regulatory baselines, resulting in a higher frequency of precautionary maneuvers.³⁰ Beyond minimum licensing requirements (i.e., responding to conjunction alerts from the 18th Space Defense Squadron) many operators also engage in pre-coordination with other satellite operators, subscribe to third-party space situational awareness services (such as

²⁷ Daniel E. Walters and Hannah J. Wiseman, “Self-Regulation in Emerging and Innovative Industries,” *Houston Law Review* 62, no. 3 (2025): 543.

²⁸ Marco Pasqua, “Bridging Soft and Hard Law in AI Governance,” BIICL Insights (blog), British Institute of International and Comparative Law, December 17, 2025, <https://www.biicl.org/blog/121/bridging-soft-and-hard-law-in-ai-governance>.

²⁹ Walt Everetts, Kenneth Rock, and Misa Iovanov, “Iridium Deorbit Strategy, Execution, and Results,” *Journal of Space Safety Engineering* 7, no. 3 (2020): 351–57.

³⁰ Hugh Lewis, “SpaceX Quietly Changed Its Approach to Space Safety,” LinkedIn, July 22, 2024, <https://www.linkedin.com/pulse/spacex-quietly-changed-its-approach-space-safety-hugh-lewis-v2ide/>.

LeoLabs), and develop internal protocols for conjunction assessment and response.³¹ These practices demonstrate how self-governance can fill gaps left by slower-moving regulatory frameworks, particularly in a rapidly evolving technological environment.

However, reliance on self-governance introduces significant variability and limitations. The extent and quality of these practices often depend on company size and technical maturity, leading to inconsistent behavior across the industry. While some operators may benefit from a stronger regulatory baseline and culture of responsible conduct, others may face fewer incentives or constraints to adopt similar standards. This disparity is especially pronounced among smaller or newer entrants, which may lack the resources or incentives to implement robust debris mitigation or collision avoidance strategies. Ultimately, while self-governance can be flexible and adaptive, it remains inherently uneven and lacks transparency and accountability. These limitations become increasingly consequential as space operations grow to become autonomous and interconnected.

Underlying Government Infrastructure

Finally, government-provided infrastructure plays a critical but often underappreciated role in orbital governance. In essence, it serves as a backbone that equips operators with baseline tools for safe and responsible operations. Platforms such as NASA's Debris Assessment Software ("DAS") support satellite design and licensing by enabling rapid evaluation of collision risk, orbital lifetime, and re-entry outcomes.³² Space-Track, powered by a global network of U.S. sensors, provides real-time tracking data, object catalogs, and conjunction alerts to operators worldwide.³³ These tools lower barriers to compliance and enable firms to develop more advanced, internal capabilities, effectively supporting self-governance without imposing additional regulatory burdens. However, they still face limitations. DAS relies on simplified modeling assumptions, and Space-Track's data, while comprehensive, requires ongoing modernization through the DoC's Traffic Coordination System for Space (TraCSS) initiative to keep pace with growing orbital congestion.³⁴ Overall, this infrastructure enhances situational awareness and coordination, but also reinforces reliance on U.S.-provided systems and emphasizes the need for continued investment and interoperability as space activity expands.

³¹ Jason Rainbow, "Connecting the Dots: Improving Satellite Collision Predictions for Efficient Space," SpaceNews, June 23, 2022, <https://spacenews.com/connecting-the-dots-improving-satellite-collision-predictions-for-efficient-space/>; Combined Force Space Component Command, *Spaceflight Safety Handbook for Satellite Operators, Version 1.7* (April 2023), https://www.space-track.org/documents/SFS_Handbook_For_Operators_V1.7.pdf.

³² NASA, "Debris Assessment Software," accessed August 1, 2026, <https://orbitaldebris.jsc.nasa.gov/mitigation/debris-assessment-software.html>.

³³ Space-Track.org, "Documentation," accessed August 1, 2026, <https://www.space-track.org/documentation>.

³⁴ See National Research Council, *Limiting Future Collision Risk to Spacecraft: An Assessment of NASA's Meteoroid and Orbital Debris Programs* (Washington, DC: National Academies Press, 2011), 27; U.S. Department of Commerce Office of Space Commerce, "Commerce Department's New Traffic Coordination System for Space Launches Initial Capabilities," September 30, 2024, <https://space.commerce.gov/commerce-departments-new-traffic-coordination-system-for-space-launches-initial-capabilities/>.

Regulation & Innovation

Before making the decision of what type(s) of governance instruments to adopt, it is crucial to understand the trade-offs implicated when choosing one instrument over another.

More stringent regulations may lead to safer operation on-orbit but could also inhibit innovation, e.g., by restricting company activities or by prescribing spacecraft design and operation. Likewise, deferring to company best practices may promote industry innovation but could result in unsafe and harmful company practices. There could be a middle ground where the companies within the same industry share best practices and enforce those best practices through peer pressure, contractual mandates, or other informal processes. All three possibilities play a part in regulating the future of the American commercial space industry. But legal formalization in particular has the ability to constrain the capital- and time-intensive industry to an extent that could significantly alter the future of the industry. Understanding legal formalization and where it was used successfully, and unsuccessfully, is critical to understanding its place in the future of commercial space.

Proactive vs. Reactive Policymaking

Proactive and reactive policymaking is closely linked to the broader trade-off between regulation and innovation. Historically, space law has adapted rather reactively in response to notable incidents rather than anticipating them.³⁵ While responding reactively enables policymakers to learn from real-world experience and avoids unnecessary innovation constraints, it can present significant risks. A single failure within the space domain can produce long-term consequences that may be impossible to reverse.³⁶ Proactive policymaking seeks to establish rules, standards, and safeguards before incidents occur. For example, in the context of AI-enabled space operations, this might include establishing requirements for human oversight or defining acceptable levels of autonomy. However, proactive policy operates within a spectrum of uncertainty and overly prospective rules may stifle innovation and/or become obsolete.

Hence, a fundamental trade-off remains. Too much regulation too early could restrict and limit benefits of technological advances. Too little regulation too late may allow risks to proliferate in ways that become difficult to manage.³⁷ The space domain remains both strategically significant and physically fragile, so this trade-off can be precarious. Ultimately, the challenge for space policymakers will be calibrating when and where proactive and reactive policy is appropriate. As autonomy increases, governance frameworks must evolve to anticipate high-risk scenarios without prematurely constraining innovation.

³⁵ See Sivan Shlomo-Agon and Michal Saliternik, “Accelerating Beyond Earth: Why Space Law Needs to Get Ahead of the Reactive Curve,” *University of Pennsylvania Journal of International Law* 47 (2026): 1086.

³⁶ Slava G. Turyshv, “Orbital Debris in Earth Orbit: Operations, Stability, Control, and Market Formation,” *Acta Astronautica* 247 (October 2026): 652–68.

³⁷ The precautionary principle also offers a useful analytical lens here. In its weaker form, the principle permits regulation under conditions of scientific uncertainty. In its stronger form, the principle shifts the burden onto operators to demonstrate safety before engaging in potentially harmful activities. See John S. Applegate, “The Taming of the Precautionary Principle,” *William & Mary Environmental Law and Policy Review* 27 (2002): 13.

Prevention & Liability

Another useful lens to analyze space governance is to distinguish between *prevention* and *liability*, which address different points in the lifecycle of risk. Prevention focuses on what rules, standards, and oversight mechanisms apply *before* an interaction occurs, such as licensing requirements, coordination protocols, data sharing, and operational constraints designed to reduce the likelihood of collisions or harmful interference. Liability, by contrast, addresses what happens *after* harm occurs, including how responsibility is assigned and how damages are compensated. Existing frameworks, most notably the Liability Convention, provide mechanisms for attributing responsibility, but are largely reactive, state-centric, and often ill-suited for complex, modern scenarios involving private actors and autonomous systems. As a result, prevention and liability are frequently treated as separate though individually incomplete regimes. Prevention mechanisms may lack enforceability or consistency, while liability frameworks struggle with attribution, causation, and scope of damages. Bridging this gap proves critical for ensuring both effective risk mitigation and credible accountability in an increasingly congested and autonomous space environment.

Autonomy

While autonomy is not the primary governance problem of this report, it is a complicating condition layered on top of more fundamental gaps in orbital governance. The first-order challenge in modern space operations proves to be the absence of sufficiently developed standards for coordination, collision avoidance, proximity operations, and operational oversight in an increasingly congested orbital environment. Existing governance frameworks still lack binding “rules of the road” comparable to those found in maritime or aviation law, leaving many operational decisions to voluntary standards, self-governance, and ad hoc coordination between commercial and/or state operators.³⁸ In this context, autonomous systems manifest throughout the space economy as a practical response to scale. Large constellation operators have increasingly adopted automated collision avoidance systems since the volume and frequency of conjunction events make fully human-in-the-loop decision-making operationally unrealistic.³⁹ Therefore, rather than destabilizing, autonomy can be viewed as necessary for maintaining safety and maneuvering responsiveness in an environment where governance infrastructure remains incomplete.

Nevertheless, autonomy poses an additional layer of governance challenges that persist even if stronger baseline operational frameworks become established. For example, autonomy will further complicate fault attribution. Traditional liability regimes presume that harmful outcomes can be traced to identifiable human decisions, whether by an operator, regulator, or

³⁸ Dan McCormick, Douglas C. Ligor, and Bruce McClintock, *Cross-Domain Lessons for Space Traffic Management: An Analysis of Air and Maritime Treaty Governance Mechanisms* (Santa Monica, CA: RAND Corporation, 2023), https://www.rand.org/pubs/research_reports/RRA2208-2.html.

³⁹ Madeline Durrett, “Rethinking Satellite Operations: More Autonomy Key to Fewer Collisions,” *Constellations*, February 10, 2026, <https://www.kratospace.com/constellations/articles/rethinking-satellite-operations-more-autonomy-key-to-fewer-collisions>.

manufacturer.⁴⁰ Autonomous systems obfuscate this logic because the immediate operational decision may be generated algorithmically, with no discrete human action to evaluate after an incident occurs. This creates a structural gap in both domestic tort frameworks and international liability regimes, particularly where fault-based standards require demonstrating negligence or unreasonable conduct. Furthermore, bilateral autonomous avoidance also proves problematic. Even if two operators independently deploy well designed autonomous collision avoidance systems that comply with all applicable standards, their systems may still interact in unpredictable ways that produce collectively suboptimal or even dangerous outcomes. Two autonomous spacecraft responding simultaneously to the same conjunction event, for example, could unintentionally maneuver into greater risk rather than away from it. Ultimately, autonomy raises imminent questions about how independently designed autonomous actors behave within a shared orbital environment lacking centralized traffic management and binding coordination protocols.

⁴⁰ Alex S. Li, “Autonomizing Outer Space: Updating the Liability Convention for the Rise of Artificial Intelligence (AI),” *UC Irvine Law Review* 15 (2024): 82.

A. Intentional Interactions

Introduction

Intentional interactions are proximity operations in which an active spacecraft deliberately maneuvers to approach, inspect, capture, service, or remove another spacecraft or space object. Unlike conjunctions that arise from orbital mechanics alone, these interactions are affirmative operational choices: a mission planner decides to close the distance, and the spacecraft executes that decision, often autonomously. This distinguishes them as a governance category not merely because the harm they can cause is foreseeable, but because the decision to create the risk is itself deliberate. That deliberateness raises questions that unintentional interactions do not: what authorization should be required before an approach begins, what standard of care governs the encounter itself, and how responsibility should be allocated when an intentional operation produces unintended consequences.⁴¹

The three sub-categories addressed in this section reflect the range of objects that an active spacecraft may intentionally approach. First, interactions between two active spacecraft, typified by commercial on-orbit servicing and refueling missions. Second, interactions between an active spacecraft and a registered but inactive object, such as a dead satellite whose owner retains legal jurisdiction even though the object can no longer maneuver. Third, interactions with unregistered or effectively abandoned debris, most commonly in the context of active debris removal. These categories share a common governance architecture and a common set of structural gaps, but each also presents legal questions that are specific to the character of the target object.

Commonly Applicable Governance Regimes

Hard Law

Across all three intentional interaction categories, U.S. missions must navigate the Outer Space Treaty and Liability Convention at the international level and a patchwork of domestic licensing, debris-mitigation, and safety statutes at a domestic level. Article VI and Article VIII of the Outer Space Treaty make the U.S. internationally responsible for national activities in space and require authorization and continuing supervision. The Liability Convention provides a process to hold states responsible on an absolute-liability basis for Earth-surface damage and on a fault basis for damage in space.⁴² Domestically, the Commercial Space Launch Act and the FAA's Part 450 rules govern launch, reentry, payload review, and end-of-launch debris mitigation.⁴³ The FCC now imposes orbital-debris and post-mission disposal conditions, including a five-year disposal timeline for many new LEO systems. Other proposals such as the

⁴¹ The unintentional interactions section addresses conjunction events arising from orbital mechanics rather than deliberate approach. However, some governance challenges identified in the intentional interactions section, particularly those involving fault attribution and the absence of binding operational standards, also bear on unintentional interactions.

⁴² See Outer Space Treaty, arts. VI, VIII; Liability Convention, arts. II–III.

⁴³ See Commercial Space Launch Act, 51 U.S.C. § 50901 et seq.; 14 C.F.R. pt. 450 (2021).

ORBITS Act and DoC’s emerging Space Commerce Certification signal a move toward mission authorization for novel on-orbit activities.⁴⁴ None of these instruments, however, is tailored to one particular intentional interaction type.

Industry Standard

A shared set of industry standards also cuts across all three intentional interaction categories. Technical documents such as the Consortium for Execution of Rendezvous and Servicing Operations (“CONFERS”) recommended practices and International Organization for Standardization (“ISO”) standard 24330 describe approach-corridor design, keep-out zones, and abort-safe trajectories for rendezvous and proximity operations, and they are used by operators whether the target is an active client satellite, a dead satellite, or a large derelict.⁴⁵ Debris-mitigation guidelines like the Inter-Agency Space Debris Coordination Committee Space Debris Mitigation Guidelines (“IADC Guidelines”) and the U.S. Government Orbital Debris Mitigation Standard Practices (“ODMSP”) likewise apply regardless of what object a mission plans to approach, shaping mission design choices about end-of-life disposal, passivation, and collision-risk management for all U.S.-licensed spacecraft.⁴⁶ These instruments are generally non-binding, but regulators can incorporate them by reference in license conditions, and operators increasingly treat them as the de facto technical playbook for intentional close-approach missions.

Self-Governance

U.S. operators’ internal “flight rules” and constraints additionally apply on top of legal and industry requirements. These company-level rules typically designate their own internal numerical thresholds for when to maneuver or abort a mission, define safe-approach geometries and keep-out zones, and decide how much to rely on autonomy in the terminal phase. Operators also choose how much to share their ephemeris data and how much to coordinate based on tools

⁴⁴ See ORBITS Act of 2025, S. 1898, 119th Cong. (2025); U.S. Department of Commerce Office of Space Commerce, *Department of Commerce Proposal Responding to Executive Order 14335 Section 5* (March 2026), 2–3, <https://space.commerce.gov/wp-content/uploads/2026/03/Space-Commerce-Certification-OSC-Proposal-March-2026.pdf>.

⁴⁵ See Consortium for Execution of Rendezvous and Servicing Operations (CONFERS), *CONFERS Recommended Design and Operational Practices*, October 2022, https://cdn.ymaws.com/satelliteconfers.org/resource/resmgr/confers_publications/confers_operating_practices_.pdf [hereinafter CONFERS Recommended Practices]; International Organization for Standardization, *ISO 24330:2022(en) Space Systems–Rendezvous and Proximity Operations (RPO) and On-Orbit Servicing (OOS) — Programmatic Principles and Practices* (Geneva: ISO, 2022), <https://www.iso.org/standard/78463.html> [hereinafter ISO 24330:2022].

⁴⁶ See Inter-Agency Space Debris Coordination Committee (IADC), *IADC Space Debris Mitigation Guidelines*, IADC-02-01, rev. 4 (2025), https://www.unoosa.org/res/oosadoc/data/documents/2025/aac_105c_12025crp/aac_105c_12025crp_9_0.html/AC1_05_C1_2025_CRP09E.pdf; U.S. Government, U.S. Government Orbital Debris Mitigation Standard Practices (Washington, DC: Office of Science and Technology Policy, 2019), https://www.orbitaldebris.jsc.nasa.gov/library/usg_orbital_debris_mitigation_standard_practices_november_2019.pdf.

such as Conjunction Data Messages, tracking services from the U.S. Space Force, CONFERS, or the Space Safety Coalition.⁴⁷ Each operator can vary on how they choose to manage risk whenever they intentionally bring one spacecraft near another object. These self-governance measures apply across interaction types, but because they are proprietary and unevenly adopted, they introduce additional variability to the already shaky foundation set by hard-law and industry standards.

Private Ordering Between Companies

Related to self-governance are the contractual agreements between spacecraft operators. Contracts function as a form of private ordering whereby contractual parties establish customized rules and standards of conduct. Most importantly, a contract does not reach parties outside its scope. Third-party operators threatened by debris from a failed docking have no arbitral agreement and no direct path to relief. Likewise, arbitration and contractual dispute resolution cannot address the full scope of harms autonomous spacecraft interactions are likely to generate. In cases involving autonomous space operations, dispute resolution is further constrained by the “black box problem.” When the decision causing harm is algorithmic, establishing a coherent theory of fault and causation is difficult, and a servicer can plausibly invoke contractual liability caps by arguing no binding standard governed its system’s design. Contractual confidentiality precludes the standard-setting the servicing industry needs. If disputes are resolved through arbitration, which is confidential, this also prevents outside parties from evaluating these cases and deriving what reasonable autonomous RPOD standards could look like.

Common Governance Gaps

Intentional interactions share a common characteristic: they are planned activities with defined execution strategies for close-proximity operations. The primary regulatory challenges lie in determining (i) what prior coordination is required to ensure U.S. compliance with international treaty obligations, (ii) who approves such plans, and (iii) clear attribution of liability in the event of a collision.

Fragmented Institutional Authority & Lack of Mission Specific Authorization

Intentional proximity operations fall between existing regulatory regimes. No single agency has clear, comprehensive authority over the on-orbit encounter itself, including approach, inspection, docking, capture, abort planning, autonomy safeguards, and third-party risk. As a result, an operator may secure the required launch and communications approvals from various agencies without any unified mission-specific review of the highest-risk phase of the activity: the deliberate close-proximity operation in orbit.

⁴⁷ See Space-Track.org, “Documentation,” accessed August 1, 2026, <https://www.space-track.org/documentation>; Space Safety Coalition, Best Practices for the Sustainability of Space Operations (2019), <https://spacesafetycoalition.org/best-practices/>

Although every FCC-licensed spacecraft launched must obtain approval of its orbital debris management plan from the FCC, including provisions for planned proximity operations, the current framework lacks mission-specific authorization. The FCC's new Part 100 rules require applicants engaging in rendezvous and proximity operations ("RPO") to identify the spacecraft involved, provide a statement disclosing the planned proximity operations, and provide registration information or the expected State of Registry for any foreign objects involved.⁴⁸ Nonetheless, these rules impose a disclosure requirement rather than amount to an authorization regime. While the RPO operator must inform the FCC of its plans, no agency conducts a substantive mission-specific review of the RPO itself, nor determines whether additional approvals or international coordination may be required. Moreover, such authorization would necessarily vary across different categories of intentional interactions. Operations between two U.S.-registered spacecraft present different considerations than those involving a U.S. spacecraft and a foreign-registered one. The complexity increases further when unregistered space objects are involved, as there may be no identifiable counterpart with which to coordinate.

Liability

The liability regime is also largely silent on the attribution of fault when anomalies occur during proximity operations, particularly if they result in debris generation or damage to any spacecraft. In cases involving two U.S. operators, dispute resolution can generally be handled at the domestic level. Nonetheless, the absence of binding operational standards for proximity operations means that fault determination lacks an established benchmark. However, when foreign space operators are involved, claims could be elevated to the state-to-state level in accordance with the Liability Convention, adding complexity to both attribution and enforcement.⁴⁹ In this scenario, foreign space operators might bring a claim based on the theory that U.S. regulators failed to supervise adequately. For example, the operators may attempt to argue that no regulatory framework required U.S. regulators to review the onboard autonomous approach system. Yet, such a claim has never been tested before any international tribunal. The Liability Convention's claims process depends on diplomatic negotiation with no binding arbitration mechanism. The only formally pursued Liability Convention case, arising from the Cosmos-954 incident, resulted in Canada claiming CAD 6 million and settling for CAD 3 million paid three years after the event, following extended diplomatic negotiation with no binding arbitration.⁵⁰

Dispute Resolution

Without a codified standard of care specific to intentional close-approach maneuvers, regulators and courts are left to reconstruct what "reasonable" conduct looks like after collision incidents. This process will likely involve expert testimony, which is expensive and could produce inconsistent outcomes that fail to meaningfully improve future operator behavior.

⁴⁸ FCC 2026 Order, Appendix A, § 100.111(f).

⁴⁹ Liability Convention, arts. III, VIII–IX; *see also* United Nations Office for Outer Space Affairs, "Liability Convention," accessed May 17, 2026, <https://www.unoosa.org/oosa/en/ourwork/spacelaw/treaties/liability-convention.html>

⁵⁰ Agreement Between Canada and the Union of Soviet Socialist Republics Concerning the Settlement of Canada's Claim for Costs Incurred as a Result of the Cosmos 954 Incident, Apr. 2, 1981, 20 I.L.M. 689.

Currently, few dedicated forums exist for resolving on-orbit collision disputes, though specialized options like the Permanent Court of Arbitration’s optional rules for outer space disputes and Dubai International Financial Centre Courts of Space are emerging.⁵¹ However, because no statutory process mandates their use, operators still navigate a patchwork of domestic torts, regulatory proceedings, and generic arbitration.

Autonomy

Autonomy compounds these governance gaps. Planned proximity operations increasingly rely on onboard systems to make or execute time-sensitive decisions during approach, station-keeping, abort, and capture.⁵² In that setting, the relevant decision may not be a discrete human command but a sequence of software-mediated responses to sensor inputs, relative-motion estimates, and pre-programmed mission rules. If an autonomous system selects an approach path, delays a maneuver, or initiates an abort that a human operator might not have chosen, fault becomes harder to assign after the fact. Current law does not clearly define what levels of autonomy are acceptable for intentional proximity operations, what safeguards must accompany autonomous maneuvering, or what evidence operators must preserve to reconstruct an autonomous failure. That uncertainty leaves the fault standard open-ended. Regulators and courts may need to determine questions of fault without clear standards.

⁵¹ Permanent Court of Arbitration, Optional Rules for Arbitration of Disputes Relating to Outer Space Activities, December 6, 2011, <https://docs.pca-cpa.org/2016/01/Permanent-Court-of-Arbitration-Optional-Rules-for-Arbitration-of-Disputes-Relating-to-Outer-Space-Activities.pdf>; DIFC Courts, “Dubai’s Courts of Space Launches International Working Group to Explore Space-Related Legal Innovations,” April 20, 2021, <https://www.difccourts.ae/media-centre/newsroom/dubais-courts-space-launches-international-working-group-explore-space-related-legal-innovations>.

⁵² Jesse Mulvaney et al., *2025 ISAM State of Play* (Washington, DC: NASA, 2025), 1–2, 17–18, https://ntrs.nasa.gov/api/citations/20250008988/downloads/NASA_ISAM_State_of_Play_2025_Edition.pdf.

(1) Intentional U.S. Private Spacecraft ↔ Spacecraft Interactions

Intentional interactions between active spacecraft are expected to increase rapidly as the on-orbit servicing industry expands. These interactions can take several forms, including assisted orbit transfer, refueling, and close-proximity inspection. Proximity and docking operations introduce inherent risks since satellites can pose hazards to one another, particularly when maneuvers are conducted autonomously and real-time decisions are made at the edge.

Illustrative Scenario

A U.S. commercial servicing company maneuvers a propellant tanker to dock at a client's geosynchronous Earth orbit ("GEO") spacecraft. Both operators have coordinated the approach, but the terminal phase runs autonomously. A software error causes the tanker to close faster than planned. The tanker crashes into the client spacecraft, damaging both spacecraft and generating debris that forces avoidance maneuvers by two nearby third-party spacecraft. The harm flows directly from an affirmative operational choice to approach.



(Figure 1. Illustrative scenario: intentional interaction between two active spacecraft)

Specific Governance Gaps

The gaps identified below are: prevention gaps (what the framework fails to require before an intentional interaction is attempted); liability gaps (how responsibility is assigned after harm results); and autonomy gaps (how the autonomous system creates additional legal complexity).

Prevention Gaps

As mentioned, the most fundamental prevention gap is the absence of a mission-specific authorization regime for commercial RPOD in the U.S. The agencies that might regulate on-orbit servicing (FCC, FAA, DoC) were designed for distinct mission phases, and none holds statutory authority to impose operational safety requirements on the on-orbit approach itself.

Another key issue is the absence of any international pre-approach notification requirement. International law imposes no obligation on a servicing operator or its supervising state to notify third parties, publish approach corridor data, or share RPOD trajectory plans before beginning terminal approach. The debris generated by the hypothetical impact threatened third-party satellite operators who had no advance opportunity to increase their collision avoidance readiness, despite a mandatory pre-approach notification window being technically straightforward to implement. Domestically, notwithstanding the FCC's new rules, no binding instrument requires an operator to notify potentially affected third parties a set time before approach so that the other party may make preparations, such as elevating collision avoidance readiness.⁵³ There is also an absence of any binding standard of care for autonomous RPOD. As servicing missions increasingly rely on autonomous onboard decision-making during the final approach, the question of what constitutes adequate autonomous system design becomes central to both prevention and liability. CONFERS guidance recommends abort-safe trajectory design but does not specify software verification and validation requirements or sensor redundancy standards, and no binding standard governs autonomous RPOD system certification.⁵⁴

Liability Gaps

There is no direct cause of action for private operators. The client operator's practical remedy is its commercial contract with the servicing company and applicable domestic tort law, but any contractual limitation-of-liability clause could cap the servicing company's exposure well below the client's estimated losses. Third-party operators who suffered fuel losses from avoidance maneuvers and face elevated collision risk from new GEO debris have no contractual relationship with the servicing company and may be left with state-to-state Liability Convention claims.

Autonomy

GEO servicing missions operate without real-time human command authority during terminal approach because round-trip communication latency at geostationary altitude makes

⁵³ The FCC's new Part 100 rules require all space-station licensees and market-access recipients to submit accurate and timely ephemeris data, including propagated ephemeris and covariance for planned maneuvers, to the 18 SDS and to FCC-identified SSA systems. FCC 2026 Order, Appendix A, § 100.201(c). In addition, RPO applicants must disclose planned proximity operations at the licensing stage. 100.111(f).

⁵⁴ See CONFERS Recommended Practices (recommending abort-safe trajectory design without specifying software verification, validation, or sensor redundancy requirements); U.S. Department of Commerce Office of Space Commerce, *Department of Commerce Proposal Responding to Executive Order 14335 Section 5* (March 2026), 2–3, <https://space.commerce.gov/wp-content/uploads/2026/03/Space-Commerce-Certification-OSC-Proposal-March-2026.pdf> (acknowledging the absence of binding certification standards for autonomous RPOD systems as a gap the OSC proposal seeks to address).

human-in-the-loop control physically impractical. As missions extend to LEO servicing, debris removal, and orbital transfer, autonomous decision-making will extend even earlier in the approach sequence.

The governance framework was not designed for this. Existing fault standards frameworks, e.g., the Liability Convention, presuppose a human decision that caused the harm (an operator who chose to approach at an unsafe velocity or a regulator who failed to require a safety check).⁵⁵ When the harmful decision is algorithmic, the causal chain runs through software design choices made months or years before the mission, by engineers whose identities may be difficult to establish in litigation and whose design choices were never reviewed by any external authority. The “black box” problem (the difficulty of reconstructing why an autonomous system made a specific decision) makes fault attribution technically complex, legally novel, and practically expensive even when the damage is clear.

Moreover, the absence of a binding regulatory standard could make the fault determination circular. There is no external benchmark against which the servicing company’s design choices can be evaluated as reasonable or negligent because no such standard exists in U.S. domestic regulation, international treaty law, or any binding industry framework. In turn, to determine the applicable standard of care, courts or regulators may refer to industry practice, including the servicing company’s own conduct.

Autonomy also confounds the prevention framework. CONFERS and ISO 24330, the most operationally detailed governance instruments currently applicable to RPOD, address approach corridor geometry, keep-out zones, and abort-safe trajectory design.⁵⁶ But these are all concepts that assume a human operator is making real-time decisions about whether to proceed. They do not address the software verification and validation standards, sensor fusion architectures, or failure mode analyses that govern what an autonomous system does when its environmental model diverges from reality. Filling the autonomous RPOD governance gap therefore requires not just extending existing RPOD standards to new missions but developing a qualitatively different type of standard that governs system design and pre-mission certification rather than real-time operational conduct.

Analysis: Formalization and Innovation–Regulation Trade-off

No agency holds statutory authority over the on-orbit approach itself. The FAA’s boundary at orbital insertion and the FCC’s spectrum-only mandate are narrow. Filling this gap would require either new statutory authority or a creative reading of DoC’s existing power under 51 U.S.C. § 50702. The Office of Space Commerce (“OSC”) Space Commerce Certification proposal gestures toward the latter but, because it is voluntary, attempts to address the gap without resolving it.

⁵⁵See Liability Convention, arts. II–III; see also Theresa Hitchens, “Autonomy Has Outpaced International Space Law,” War on the Rocks, Mar. 14, 2025, <https://warontherocks.com/2025/03/autonomy-has-outpaced-international-space-law/> (arguing that the Liability Convention’s fault framework “implicitly assumes human decision-making” and was not designed to address harm caused by autonomous systems).

⁵⁶See CONFERS Recommended Practices; ISO 24330:2022.

The notification gap is a coordination problem that may have the clearest solution. Notification requirements are behaviorally simple, impose minimal compliance costs, and require no setting of technical standards. A binding domestic requirement imposed as an FCC license condition could address the gap for U.S.-licensed operators without new legislation, while creating a basis for reciprocal obligations. The primary obstacle would be political, however, as states with active RPOD programs may resist requirements that could constrain proximity operations for national security purposes.

The autonomous standard-of-care gap may be the most technically complex. Because autonomous guidance technology is evolving rapidly, prescriptive design requirements risk locking in standards that impose costs without producing safety benefits as the technology shifts. A performance-based approach that specifies required outcomes rather than design choice may be more durable, but any standard still requires an agency with authority to impose and regulate it.

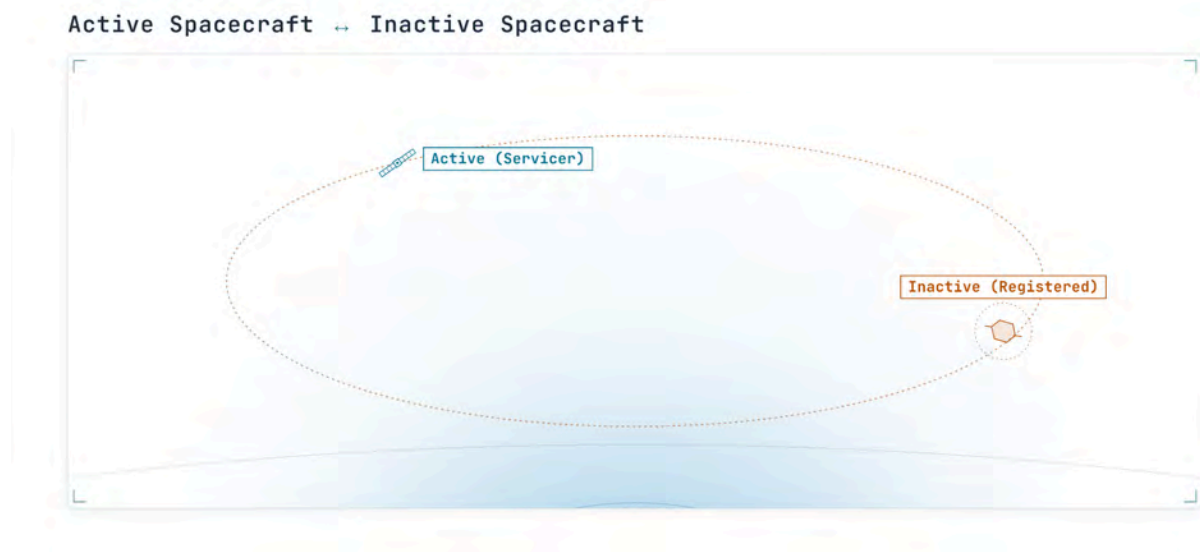
In terms of the liability gaps, what domestic law can do is dissolve the circularity. If a binding autonomous RPOD standard exists and an operator violates it, the Article VI supervisory failure becomes easy to demonstrate. Extending financial responsibility requirements to cover on-orbit operations would also ensure that private remedies are backed adequately and would create insurance market incentives that could organically generate underwriting standards for autonomous system design.

(2) Intentional U.S. Private Spacecraft ↔ Registered Inactive Spacecraft

Intentional interactions between active spacecraft and registered inactive spacecraft are likely to become commonplace in the near future. Commercial companies and governments are investing in technologies to deorbit inactive spacecraft or service them. While the active spacecraft bears responsibility for conducting operations with a passive object, the legal and regulatory framework governing authorization, particularly for retrieving or servicing satellites registered by foreign nations or the U.S., remains unclear.

Illustrative Scenario

A U.S.-licensed private servicing spacecraft attempts to dock with an inactive communications spacecraft parked in a graveyard orbit. The servicing operator has obtained launch authorization, payload determination, and communications licenses from the relevant U.S. agencies, and has secured a commercial agreement with the target satellite's last known operator of record. During final approach, the inactive spacecraft is rotating in a way that pre-mission tracking did not fully capture, the servicer's onboard guidance system misreads the relative geometry, and the robotic arm strikes the target's solar array. The collision generates fragments and disturbs both spacecraft's trajectories. As the servicer attempts to retreat, the altered relative motion drives it into the inactive spacecraft's main body, producing additional debris that drifts toward orbital positions occupied by active communications spacecraft.



(Figure 2. Illustrative scenario: intentional interaction between an active spacecraft and a registered inactive spacecraft)

Specific Governance Instruments

The starting point is the Outer Space Treaty, which the U.S. ratified in 1967.⁵⁷ Article VI says that states are internationally responsible for national activities in outer space, including activities carried out by private entities, and that those activities require authorization and continuing supervision. Article VIII provides that the state on whose registry an object launched into outer space is carried retains jurisdiction and control over that object while it remains in outer space.⁵⁸ These rules matter in the inactive spacecraft setting because a spacecraft does not become legally ownerless just because it no longer works. If the inactive spacecraft remains on a national registry, the registry state still has legal authority over it.⁵⁹ That means another operator’s attempt to capture, move, or service it is not just a technical question. It also raises a question of consent, sovereignty, and legal control. Furthermore, the Liability Convention addresses damage, but it does so in a way that fits awkwardly with modern spacecraft servicing. The Convention imposes absolute liability for damage on Earth or to aircraft in flight.⁶⁰ For damage in space, however, it uses a fault-based rule: a launching state is liable only if the damage was caused by its fault or the fault of persons for whom it is responsible.⁶¹ This creates two problems in the servicing context. First, claims are brought by states, not directly by private

⁵⁷ U.S. Department of State, “Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies,” 2009–2017 *State.gov Archive*, accessed May 17, 2026, <https://2009-2017.state.gov/t/isn/5181.htm>.

⁵⁸ Outer Space Treaty, arts. VI, VIII. The Outer Space Treaty uses the umbrella term “object launched into outer space.” For the purposes of this report, the term encompasses both “spacecraft” and “space object” as defined above.

⁵⁹ Outer Space Treaty, art. VIII.

⁶⁰ Liability Convention, art. II.

⁶¹ Liability Convention, art. III.

spacecraft operators.⁶² Second, the Convention does not explain what fault means in a mission involving an inactive spacecraft, close maneuvering, and automated systems.⁶³ It does not say what counts as reasonable and foreseeable in a tort sense, especially regarding automation.⁶⁴

U.S. domestic law provides part of the answer. The CSLA authorizes the federal government to issue licenses and impose conditions necessary to protect public health and safety, safety of property, national security, and U.S. foreign policy interests.⁶⁵ The FAA’s implementing regulations, especially Part 450, require launch licensing, payload review, collision analysis for launch and reentry, and end-of-launch debris mitigation such as anti-fragmentation steps and passivation.⁶⁶ Those rules are important, but they do not create a full operational code for satellite servicing after launch. The FAA’s system is strongest at the beginning of the mission. It is much thinner when the spacecraft later performs close-proximity operations around another object in orbit.

The same is true of FAA payload review. Under 14 C.F.R. § 450.43, applicants must show that they have obtained all required licenses, authorizations, and permits, and they must describe intended payload operations during the payload’s lifetime.⁶⁷ But the rule also makes clear that the FAA does not decide matters that fall within the regulatory authority of the FCC or the DoC.⁶⁸ Payload review is therefore better understood as an interagency checkpoint than as a complete mission authorization for satellite servicing.

The FCC has taken significant steps to address this gap. In 2022, it opened the proceedings on a new framework for licensing in-space servicing, assembly, and manufacturing (“ISAM”) spacecraft.⁶⁹ In 2025, the FCC launched a broader “Space Modernization” proceeding. Eventually, in 2026, the FCC adopted new rules to replace Part 25 with a new Part 100 and create a new Variable Trajectory Space Station (“VTSS”) category for ISAM and other non-traditional missions.⁷⁰ In doing so, the FCC closed its separate 2024 ISAM docket, folding those missions into the general Part 100 framework rather than developing bespoke ISAM rules.⁷¹ The new rules go beyond spectrum use alone. They address orbital debris and questions related to maneuvering and rendezvous and proximity operations.⁷² Even so, the adopted rules still do not amount to a complete federal code for close approach conduct during servicing missions. They represent an important, though incomplete, step.

⁶² Liability Convention, arts. II–III.

⁶³ Liability Convention, art. III.

⁶⁴ Liability Convention, art. III.

⁶⁵ Commercial Space Launch Act, 51 U.S.C. § 50905, <https://uscode.house.gov/view.xhtml?edition=prelim&path=%2Fprelim%40title51%2Fsubtitle5%2Fchapter509>.

⁶⁶ 14 C.F.R. §§ 450.31, 450.43, 450.169, and 450.171 (2026), <https://www.ecfr.gov/current/title-14/chapter-III/subchapter-C/part-450>.

⁶⁷ 14 C.F.R. § 450.43 (2026), <https://www.ecfr.gov/current/title-14/chapter-III/subchapter-C/part-450/subpart-B/section-450.43>.

⁶⁸ 14 C.F.R. § 450.43 (2026).

⁶⁹ FCC 2026 Order ¶ 342.

⁷⁰ FCC 2026 Order ¶¶ 4-5.

⁷¹ FCC 2026 Order ¶ 342.

⁷² FCC 2026 Order, Appendix A, §§ 100.111(e)–(f), 100.201.

Other official sources point in the same direction. The 2022 National Strategy for In-Space Servicing, Assembly, and Manufacturing shows that U.S. policy supports this sector.⁷³ The 2019 ODMSP discusses rendezvous and proximity operations and satellite servicing, but the document presents itself as guidance and a reference point rather than a binding operational rulebook for private actors.⁷⁴ Part 440 of the FAA regulations requires insurance and reciprocal waivers of claims in connection with licensed launch and reentry activities, but those provisions are framed around launch or reentry services and do not clearly resolve who bears the financial burden of an on-orbit servicing collision years later.⁷⁵

In 2025, Executive Order 14335 directed the DoC to develop a mission-authorization process for novel space activities.⁷⁶ In March 2026, OSC released a proposed “Space Commerce Certification” process for activities such as satellite servicing, commercial space stations, and lunar operations.⁷⁷ The proposal itself is evidence that the current system is still developing. If the existing framework were already clear and unified, there would be no need to propose a new consolidated pathway.⁷⁸ However, unlike the previous focus on FAA, it seems that ISAM activities are centralizing around DoC.

Specific Governance Gaps

The inactive spacecraft case sharpens a consent and jurisdiction problem that does not arise in the active spacecraft case and takes a different form in the debris case. When the target is operational, the servicing company can negotiate directly with its operator, and the U.S. and the registry state can treat that contract as evidence of the “authorization and continuing supervision” required by Article VI of the Outer Space Treaty.⁷⁹ When the target is inactive but still registered, the operator may be insolvent, dissolved, or simply unresponsive. Yet Article VIII’s reading that the registry state’s jurisdiction and control continue indefinitely forecloses any salvage-style claim by a third-party servicer.⁸⁰ Some commentators have argued that displacement to graveyard orbit amounts to abandonment, but neither view has been authoritatively resolved, and the current framework supplies no operational default for cases that fall between them.

⁷³ Executive Office of the President, *National Strategy for In-Space Servicing, Assembly, and Manufacturing* (April 2022), <https://space.commerce.gov/national-strategy-for-in-space-servicing-assembly-and-manufacturing-released/>.

⁷⁴ U.S. Government, *Orbital Debris Mitigation Standard Practices* (November 2019), https://orbitaldebris.jsc.nasa.gov/library/usg_orbital_debris_mitigation_standard_practices_november_2019.pdf.

⁷⁵ 14 C.F.R. §§ 440.9, 440.17, and 440.19 (2026), <https://www.ecfr.gov/current/title-14/chapter-III/subchapter-C/part-440>.

⁷⁶ Exec. Order No. 14335, “Enabling Competition in the Commercial Space Industry,” 90 Fed. Reg. 40219 (August 19, 2025), <https://www.federalregister.gov/documents/2025/08/19/2025-15822/enabling-competition-in-the-commercial-space-industry>.

⁷⁷ Office of Space Commerce, “Space Commerce Certification Proposal,” March 2026, <https://space.commerce.gov/wp-content/uploads/2026/03/Space-Commerce-Certification-OSC-Proposal-March-2026.pdf>.

⁷⁸ Office of Space Commerce, “Space Commerce Certification Proposal.”

⁷⁹ Outer Space Treaty, arts. VI, VIII.

⁸⁰ Outer Space Treaty, art. VIII.

Prevention Gaps

The first problem is the absence of clear operational rules for close-proximity encounters with inactive spacecraft. While the FCC’s new Part 100 rules now require operator consent for certain proximity operations and the disclosure of ownership and registry information,⁸¹ federal law still does not set general rules for what technical checks must be completed before approach, how close a servicer may come before taking additional precautions, or what level of human oversight should be required when autonomy is used. Existing regulations address launch, reentry, and some related licensing conditions, but they do not supply a detailed rule set for the deliberate encounter itself.⁸²

The second problem is, once again, fragmented authority. No single agency has a clearly defined and comprehensive role over the exact moment when a servicing spacecraft approaches, inspects, and attempts to capture an inactive satellite.⁸³

The third problem is consent. In the hypothetical, the servicing company has a commercial agreement with the target operator. But not every inactive spacecraft will have an active operator able to grant consent. Some owners may be insolvent, inactive, or difficult to identify. Some registry states may be slow to respond. Current law does not clearly provide a procedure for resolving those situations. The basic treaty framework points toward continuing jurisdiction and control, but it does not provide a practical default process for cases in which consent cannot be secured in ordinary commercial terms.⁸⁴

Liability Gaps

Liability is also uncertain. Under the Liability Convention, the key question would be whether the damage in space was caused by fault.⁸⁵ But domestic law gives only limited guidance on what fault means in this context. The FAA’s passivation rule in Part 450 helps with end-of-launch debris prevention, but it was not written to judge whether a servicing operator acted carefully during final approach to a dead satellite.⁸⁶ The ODMSP discusses best practices, but it is not binding law. The OSC certification framework is still only a proposed rule, still under notice and comment. As a result, fault would likely be argued through expert testimony after the fact rather than measured against a settled operational standard.⁸⁷

⁸¹ FCC 2026 Order, Appendix A, §§ 100.111(e)(2)(vi), 100.111(f)(1).

⁸² 14 C.F.R. pt. 450 (2026); Federal Communications Commission, “Space Innovation; Facilitating Capabilities for In-Space Servicing, Assembly, and Manufacturing”; Office of Space Commerce, “Space Commerce Certification Proposal.”

⁸³ 14 C.F.R. § 450.43 (2026); Federal Communications Commission, “Space Innovation; Facilitating Capabilities for In-Space Servicing, Assembly, and Manufacturing,” 89 Fed. Reg. 18875 (March 15, 2024); Office of Space Commerce, “Space Commerce Certification Proposal.”

⁸⁴ Outer Space Treaty, art. VIII.

⁸⁵ Liability Convention, arts. VIII–IX.

⁸⁶ 14 C.F.R. § 450.171 (2026),

<https://www.ecfr.gov/current/title-14/chapter-III/subchapter-C/part-450/subpart-C/section-450.171>.

⁸⁷ Liability Convention, art. III; U.S. Government, *Orbital Debris Mitigation Standard Practices*; Office of Space Commerce, “Space Commerce Certification Proposal.”

Financial responsibility is also mismatched. Part 440's insurance and cross-waiver rules are tied to licensed launch and reentry activities.⁸⁸ Section 440.17 repeatedly frames the waiver obligation in terms of contractors, subcontractors, and customers involved in launch or reentry services.⁸⁹ That makes the regime easier to apply to launch accidents than to servicing collisions that occur years later in orbit. The result is a financial-responsibility framework that may be relevant at the edges but does not clearly fit the problem at hand.⁹⁰

Finally, the Liability Convention channels claims through states rather than the private operator that designed and ran the servicing mission.⁹¹ In the hypothetical, operators affected by the debris would not directly use the Convention against the U.S. servicer. Their states would need to bring claims against the U.S. That may make sense at the treaty level, but it can blur responsibility in practice because the operator that made the decisions is not the actor that appears at the formal center of the international claim.⁹²

Autonomy

In addition, autonomy matters. If an autonomous guidance system selects a path or executes an abort maneuver that a human operator would not have chosen, it becomes harder to decide how fault should be assigned. Yet current law does not clearly state what kinds of autonomy are acceptable for these missions or what safeguards must be in place. That uncertainty is one reason the fault standard remains so open-ended.

Analysis: Formalization and Innovation–Regulation Trade-off

The inactive spacecraft case calls for one targeted addition rather than a new framework. A potential direction is a default rule for proceeding when the target's registry state or original operator cannot be located or refuses to engage. The most direct policy change would tie launch or operational licensing to a structured consent process: documented good-faith outreach to the registry state, a defined waiting period, and a fallback authorization standard for cases where no response is forthcoming. This kind of procedural fix is administratively cheap, technologically neutral, and removes the barrier that currently deters approach to precisely the orphaned objects that drive long-term industry demand.

Intentional U.S. private spacecraft interactions with inactive spacecraft show a legal system that is no longer fit for purpose, especially regarding automation. International law supplies state responsibility, jurisdiction, and a state-to-state liability framework. Domestic law provides launch licensing, payload review, debris mitigation rules, insurance requirements tied to launch activities, and emerging efforts to authorize new in-space missions. But the framework still lacks a clear set of operational rules for the intentional encounter itself. The U.S. is moving

⁸⁸ 14 C.F.R. pt. 440 (2026), <https://www.ecfr.gov/current/title-14/chapter-III/subchapter-C/part-440>.

⁸⁹ 14 C.F.R. § 440.17 (2026),

<https://www.ecfr.gov/current/title-14/chapter-III/subchapter-C/part-440/subpart-A/section-440.17>.

⁹⁰ 14 C.F.R. § 440.17.

⁹¹ Liability Convention, arts. VIII–IX.

⁹² Liability Convention, arts. II–III.

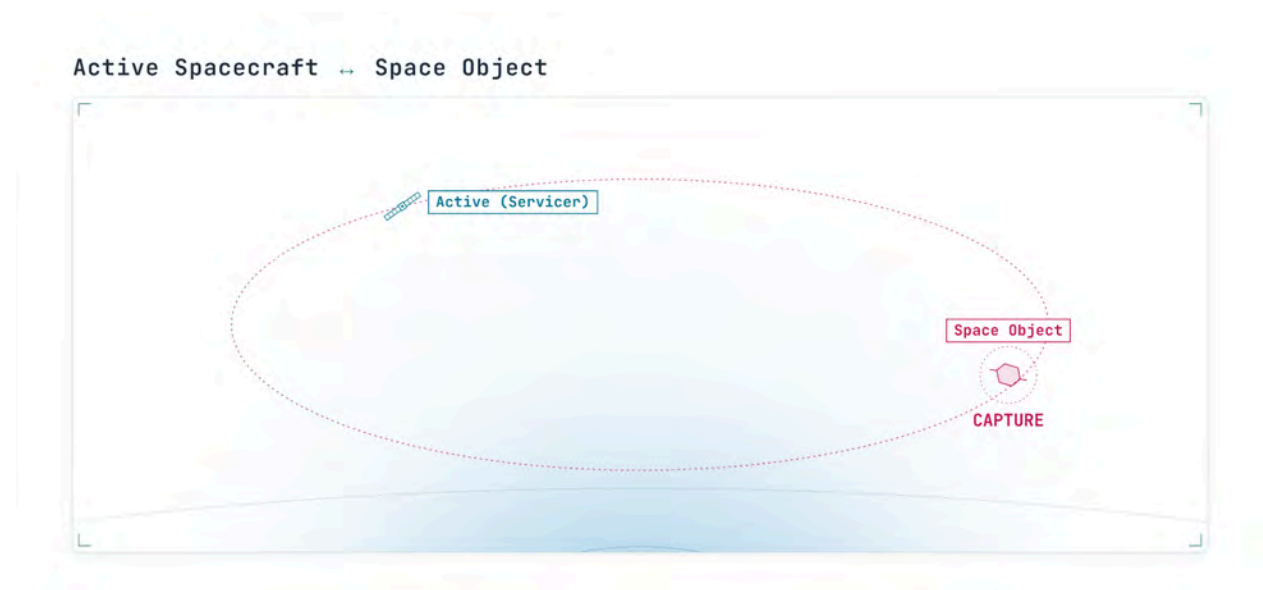
toward a future in which inactive spacecraft repair/servicing is regular and required. The law, however, is still built mainly around launch and reentry.

(3) Intentional U.S. Private Spacecraft ↔ Space Object

This section focuses on intentional spacecraft interactions with trackable, inactive space objects, such as defunct spacecraft and large debris, that are the primary targets for ADR. These interactions involve deliberate, close-proximity approaches and capture attempts of non-cooperative objects, creating distinct operational risks and governance challenges that go beyond traditional spacecraft operations based solely on collision avoidance.

Illustrative Scenario

A private ADR servicer is contracted to remove one of the five selected objects, in this case, a large derelict upper stage in a congested orbital band near 600-kilometer altitude. The mission begins with launch and orbital insertion, followed by a phasing sequence to match the target's orbit. The servicer then conducts close-proximity operations. Once in position, the servicer executes a controlled capture and performs a deorbit burn, ensuring the object reenters the atmosphere safely.



(Figure 3. Illustrative scenario: intentional interaction between an active spacecraft and an unregistered space object)

Technological Feasibility Assessment

Recent missions are beginning to establish ADR capabilities. Companies like Astroscale have demonstrated in-orbit inspection and proximity operations with non-cooperative objects, and missions such as RemoveDEBRIS have tested capture techniques in space.⁹³ Industry groups have also developed RPOD standards and best practices.⁹⁴ Building on these demonstrations, providers such as Astroscale are now positioning to offer commercial end-of-life and debris-removal services later this decade, using missions like ELSA-M as a bridge from one-off trials to recurring operations.⁹⁵

Specific Governance Instruments

The current governance regime for intentional spacecraft–space object operations is assembled from several partial instruments rather than a single, debris-specific framework. Hard law includes launch and reentry licensing under the CSLA and FAA regulations, FCC spectrum and orbital-debris-mitigation rules.

Standards and soft-law instruments that are especially relevant for intentional spacecraft–debris interactions include CONFERS recommended practices⁹⁶ and ISO rendezvous-and-proximity standards (such as ISO 24330)⁹⁷ for approaching and servicing derelict objects. Debris-mitigation guidelines like the IADC Guidelines and the ODMSP were also drafted primarily with end-of-life disposal of a mission owner’s own satellites in mind rather than capture of third-party debris. In practice, ADR operators also rely on Space-Track data and Conjunction Data Messages from the U.S. Space Force,⁹⁸ alongside self-governance through internal rules on approach distances, abort criteria, autonomy limits, safety margins during the capture phase, and private-sector debris catalogs used for debris characterization.⁹⁹

Specific Governance Gaps

Prevention Gaps

There is an absence of binding operational standards for ADR close-proximity operations. Even though the FCC’s 2026 Part 100 rules now require RPO and servicing applicants to disclose planned proximity operations, debris-generation risks, and related mitigation measures, they do not prescribe how an ADR operator must safely approach, track, or

⁹³ Astroscale, “ADRAS-J,” accessed August 1, 2026, <https://www.astroscale.com/en/missions/adras-j>; Surrey Space Centre, “RemoveDEBRIS,” accessed August 1, 2026, <https://www.surrey.ac.uk/surrey-space-centre/missions/removedebris>.

⁹⁴ CONFERS Recommended Practices.

⁹⁵ Astroscale, “ELSA-M,” accessed August 1, 2026, <https://www.astroscale.com/en/missions/elsa-m>.

⁹⁶ CONFERS Recommended Practices.

⁹⁷ International Organization for Standardization (ISO). (2022). *ISO 24330: Space Systems – Rendezvous and Proximity Operations*.

⁹⁸ Space-Track.org, “Documentation,” accessed August 1, 2026, <https://www.space-track.org/documentation>.

⁹⁹ HEO, “HEO Robotics Identifies Previously Unknown ‘Object K’ as Space Debris,” accessed August 1, 2026, <https://www.heospace.com/resources/stories/heo-robotics-identifies-previously-unknown-object-k-as-space-debris>.

capture non-cooperative debris.¹⁰⁰ ADR missions involve repeated approach, tracking, and capture of derelict objects, which carry higher risk than traditional satellite operations. As a result, regulators retain mission-specific discretion at the highest-risk phase of ADR missions, leaving operators without a consistent baseline for recurring debris-removal scenarios.

Liability and Consent Gaps

Current legal frameworks do not clearly define responsibility when an active debris removal mission causes unintended damage. If an ADR mission creates fragments that collide with a third-party spacecraft, liability is not explicitly addressed in existing rules. International agreements assign responsibility to launching states, but they do not account for modern scenarios involving private operators conducting intentional proximity operations with non-cooperative space objects.¹⁰¹ This creates uncertainty for both governments and companies. Without clear liability rules, operators face legal and financial risks that discourage high-risk removal missions. This is particularly critical in cases where an ADR mission results in fragmentation during capture or approach, creating new debris that affects third-party operators.

Furthermore, there is no clear standard for when a derelict space object can be treated as abandoned or who has the authority to authorize its removal. As discussed above, non-functional space objects remain under the jurisdiction of the original launching state, and potential successor entities or owners are not always clearly identified in practice.¹⁰² As a result, ADR operators cannot freely interact with or remove high-risk space objects without navigating an uncertain consent process that may involve multiple states and defunct or merged commercial entities. This uncertainty increases legal and diplomatic risk for missions that attempt to remove precisely the space objects that drive long-term collision risk and can delay or block removal even when technical capability and funding are available. In effect, the lack of clear abandonment and consent rules turns some of the most dangerous space objects into “legal orphans” that no one can safely touch, limiting the ability of intentional spacecraft–space object interactions to reduce congestion and systemic collision risk.

Lack of Sustained ADR Policy

Current U.S. policy does not clearly connect the problem of orbital congestion with a structured debris-removal strategy. Congress has proposed legislation to fund debris-remediation demonstration missions, though no law requires the regular removal of the most dangerous objects in orbit.¹⁰³

Autonomy and AI-Enabled Operations

For intentional spacecraft–debris interactions, autonomy and AI-enabled guidance systems create particular governance challenges because ADR missions must approach, track, and capture non-cooperative debris under tight timing and communication constraints. Existing

¹⁰⁰ FCC 2026 Order ¶ 83, Appendix A § 100.111(f).

¹⁰¹ Outer Space Treaty, art. VI; Liability Convention.

¹⁰² Outer Space Treaty, art. VIII; Liability Convention.

¹⁰³ ORBITS Act of 2025, S. 1898, 119th Cong. (2025).

licensing processes and standards do not specify how to evaluate the safety and reliability of autonomous capture algorithms in these high-risk debris-removal scenarios or how to attribute responsibility if an AI-driven decision leads to a collision with a derelict object. As a result, ADR operators and regulators must negotiate acceptable levels of autonomy and abort behavior on a case-by-case basis, adding uncertainty to missions that are already central to reducing long-term congestion.

Analysis: Formalization and Innovation–Regulation Trade-off

The gaps identified above suggest that ADR operations occupy an under-formalized zone in the formalization spectrum: the stakes are high, activity is increasing, and yet binding rules for the highest-risk phases remain thin. Leaving ADR in this zone and relying primarily on self-governance risks inconsistent safety practices and underinvestment in missions that would reduce systemic congestion, while a moratorium or highly prescriptive design rules would slow the development of needed capabilities. A targeted increase in formalization through a statute-backed removal program and integration of proximity-operations standards into licensing offers a middle path that reduces systemic risk without freezing innovation.

Policy Options

The governance gaps identified above within the intentional interactions categories call for responses at different levels of formalization and on different timescales. The policy options below are organized by feasibility and urgency.

1. Authorization & Licensing of Intentional Interactions

1.1 Short-to-Medium term: Establish a risk-tiered authorization and coordination framework for rendezvous and proximity operations

The FCC’s 2026 Order represents an important step toward formal governance of intentional on-orbit interactions. Among other requirements, the new Part 100 rules require operators engaging in RPO to provide information regarding planned interactions and related spacecraft, establish ephemeris-sharing obligations surrounding planned maneuvers and RPO, and require consent for certain operations involving related spacecraft. However, the rules stop short of establishing a generally applicable definition of proximity or specifying when increasingly stringent coordination and authorization obligations should attach as one spacecraft intentionally approaches another.

To build on Part 100, the FCC, or a future agency exercising broader on-orbit authorization authority, should establish a risk-tiered RPO framework under which regulatory obligations escalate with proximity and operational capability. The Awareness Zone could trigger identification and ephemeris-sharing requirements. The Coordination Zone could require direct operator notification and exchange of approach information. The Consent Zone could require affirmative permission from the target operator. The final and closest Physical Interaction Zone could require mission-specific authorization, continuous coordination, and defined abort

procedures. Rather than relying exclusively on fixed distance thresholds, these zones should incorporate factors such as relative velocity, maneuverability, sensor resolution, and the approaching spacecraft's capacity to observe, interfere with, or physically interact with the target.

The framework also needs to distinguish intentional proximity operations from routine conjunctions or coincidental co-orbiting spacecraft. Therefore, the framework should apply only to inter-operator encounters where a spacecraft's planned trajectory converges on, or maintains sustained proximity to, another specific object. At outer distances, sustained predicted presence (i.e., remaining within a zone across multiple orbital periods) can serve as a primary indicator of intent. By contrast, at closer distances, a planned approach trajectory toward a specific object may be sufficient. The precise thresholds would need to be established with technical input and would likely vary by orbital regime.

This framework builds on Part 100's general RPO requirements to formulate predictable operational "rules of the road" while retaining sufficient flexibility for different spacecraft and mission architectures.

Zone	Illustrative Distance	Regulatory Consequence
Awareness Zone	5-10 km	Identification + SSA/ephemeris sharing + predictable maneuver profile
Coordination Zone	1-5 km	Direct operator notification + active coordination + approach/trajectory information
Consent Zone	100 m-1 km	Affirmative consent of target operator + enhanced operational coordination
Physical Interaction Zone	0-100 m	Mission-specific authorization + explicit consent + continuous communications/telemetry + abort procedures

1.2 Medium-term: Performance-based certification for autonomous RPOD operations

The OSC Space Commerce Certification process, or a successor mandatory authorization regime established by statute, should require operators planning autonomous RPOD missions to demonstrate pre-mission that their autonomous guidance systems meet specified performance outcomes. For example, operators may be required to demonstrate abort capability at defined closure rates, sensor redundancy sufficient to maintain navigation accuracy under specified single-point failure modes, and software validation documentation adequate to reconstruct the system's decision logic post-incident. The standard should be performance-based rather than

prescriptive to accommodate technological advancements. This proposal requires either a creative statutory interpretation of OSC's existing authority or new legislation extending Commerce's authorization mandate to on-orbit operational safety, analogous to the FAA's extension of safety oversight from launch to on-orbit operations in the context of crewed commercial missions.

1.3 Medium-term: Mission-specific financial responsibility requirements for on-orbit servicing

Financial responsibility requirements should be extended via regulatory interpretation to ensure liability coverage for spacecraft-to-spacecraft servicing missions in which a U.S. operator contracts to approach, dock with, refuel, repair, inspect, or otherwise physically interact with another active spacecraft. The liability coverage can be provided through commercial insurance offering, self-insurance or agreements between operators to waive any liability claims resulting from intentional in-space interaction. These coverage levels could be calibrated based on the existing FAA-style expected maximum probable loss. This would ensure that private remedies available to the client under contract and tort law are backed by adequate financial capacity, and it would create an insurance market incentive for operators to reduce autonomous system failure risk. Insurers pricing coverage would develop their own underwriting standards for autonomous guidance systems, a form of market-driven standard-setting that could complement the performance-based certification proposal.

One hesitation about extending such requirements to all space objects or all on-orbit operations could be that it would impose substantial costs on small operators and new entrants whose missions do not involve planned close-proximity activity, thereby chilling innovation and squeezing out less capitalized actors. A narrower spacecraft-to-spacecraft servicing requirement better targets the activity that creates heightened, voluntary, and commercially compensable risk. It would also improve safety incentives without prescribing technical design choices. Insurers pricing coverage for servicing missions would demand evidence of reliable procedures, autonomous-system validation, abort capability, operator training, and post-incident data preservation. In this way, insurance and private contracts would generate market-driven safety discipline while avoiding the costs of a universal insurance mandate.

2. Formulation of a Domestic Active Debris Removal Policy

2.1 Short-term: Formulate a risk-based debris removal target list

Many of the highest-risk derelict space objects tied to the U.S. are effectively “abandoned in practice.” The original operator may have dissolved or been acquired, and no successor manages the object. Currently, there is no clear process for deciding when the U.S. will authorize its removal. To address this, NASA and the DoC should maintain a U.S. risk-based ADR target list that ranks U.S.-licensed or U.S.-affiliated derelicts in LEO using existing debris models based on mass, altitude, and collision probability. While some commercial firms¹⁰⁴ can already identify and characterize individual debris objects, this proposal would create an official U.S. government prioritization tool that links quantified collision risk to consent and funding

¹⁰⁴ HEO, “HEO Robotics Identifies Previously Unknown ‘Object K’ as Space Debris,” accessed August 1, 2026, <https://www.heospace.com/resources/stories/heo-robotics-identifies-previously-unknown-object-k-as-space-debris>.

decisions. Working with the Department of State and security agencies, the U.S. could then designate a subset of these objects as “ADR-eligible” once basic ownership and security reviews are complete. The list can be used to guide consent decisions and funding priorities for ADR missions, reducing legal ambiguity around “unowned” space objects while tying abandonment decisions directly to quantified collision risk.

2.2 Short-term: Standardized consent and ownership templates for ADR

ADR missions still face uncertainty about who can authorize removal of a derelict and how liability is allocated if something goes wrong, even when the target is a U.S.-licensed space object. To reduce this friction, U.S. regulators should develop standardized consent and ownership templates for ADR missions as part of the federal authorization process, specifying which agency grants consent, what data must be shared, how control of a derelict is transferred for the mission, and how liability is allocated if the servicer causes damage. These model clauses would be incorporated into DoC’s mission-authorization practice. They may be required whenever a U.S.-licensed operator conducts ADR on a U.S. object or in a U.S.-approved bilateral removal mission, giving operators a predictable legal pathway.

2.3 Medium-to Long-term: Adopting the proposed ORBITS Act

The proposed ORBITS Act of 2025 was introduced in response to growing congestion and debris risks in low Earth orbit. The proposal would allocate funds to NASA-led active debris removal demonstrations as a step beyond reliance on mitigation and collision-avoidance alone.¹⁰⁵ The U.S. should adopt the ORBITS Act and implement it with a clear, actionable objective for long-term orbital stabilization.

In the long term, the Act could help lay the foundation for a sustained, risk-based ADR program. Specifically, the Act should include language establishing a future target of eventually regularly removing approximately five of the highest-risk debris objects per year in LEO. This approach is consistent with NASA and IADC modeling, indicating that removals at this scale can begin stabilizing and reducing congestion in LEO.

¹⁰⁵ Orbital Sustainability (ORBITS) Act of 2025, S. 1898, 119th U.S. Congress (2025).

Table 1. Proposed Measures for Intentional Interactions

Proposal	Interaction Type	Key Actors	Time Horizon	Expected Impact	Cost	Political Feasibility	Technical Feasibility
Authorization & Licensing of Intentional Interactions							
1.1 Establish a risk-tiered authorization and coordination framework for rendezvous and proximity operations	Active ⇔ Active Active ⇔ Registered Inactive;	FCC; OSC; U.S.-licensed operators; 18th Space Defense Squadron	Short to Medium term	● Directs the new Part 100 rules towards a predictable authorization regime	●/● Builds on existing FCC rules, though defining the risk tiers requires technical assessments	● Mission-specific authorization may draw pushback from operators; question of which agency has purview over authorization	● Distinguishing intentional proximity operations from coincidental conjunctions may be demanding
1.2 Performance-based certification for autonomous RPOD operations	Active ⇔ Unregistered	OSC; Congress; RPOD operators	Medium term	● High: addresses the autonomy safety gap, without which there could be disastrous RPOD operations.	●/● High: new certification testing and technical-review capacity and staff.	●/● Industry wary of strict certification rules.	● Autonomy standards are still immature.
1.3 Mission-specific financial responsibility for on-orbit servicing	Active ⇔ Active; Active ⇔ Registered Inactive	FAA; OSC; insurers; servicing operators; satellite clients	Medium term	● Moderate: strengthens liability coverage and incentives.	● Moderate: rule change within existing FAA or OSC processes, cost falls mainly on operator premiums.	● Pushback from servicers and insurers.	● Hard to model mission-specific risk.
Domestic Active Debris Removal Policy							
2.1 Formulate a risk-based debris removal target list	Active ⇔ Registered Inactive; Active ⇔ Unregistered	NASA; OSC/TraCSS; DoS; DoD/USSF	Short term	● High: prioritizes the most dangerous derelicts and provides the authorization basis ADR currently lacks.	●/● Moderate-High: ongoing funding to build and maintain the list.	●/● Moderate-High: the cost bearer is unclear; risk criteria from defense perspective may differ from commercial prioritization.	● Analytics is feasible, but reconciling defense and commercial risk models adds complexity.
2.2 Standardized consent and ownership templates for ADR	Active ⇔ Registered Inactive; Active ⇔ Unregistered	OSC; DoS; Operators	Short term	● Moderate: removes a legal barrier, but only for cooperative-owner cases, limited reach on “unowned space objects.”	● Low: legal drafting and coordination only.	● Some concern over liability terms.	● Templates only; no new systems.
2.3 Adopting the proposed ORBITS Act	Active ⇔ Registered Inactive; Active ⇔ Unregistered	NASA; OSC/TraCSS; DoS; Congress	Medium to Long term	● Moderate: establishes federal ADR architecture and funding, but demonstration-focused and contingent on enactment.	● Moderate: requires authorization of new federal appropriations and programs.	● Depends on sustained bipartisan support.	● Uses maturing ADR/servicing tech.

Rating key: ● green marks the most favorable rating, ● red the least.

Cost: ● low ● moderate ● high

Political feasibility: ● high ● moderate ● low

Technical feasibility: ● high (least barriers) ● moderate ● low

B. Unintentional Interactions

Introduction

Unintentional interactions are classified as close approaches that arise from independent operations in orbit when there was no prior objective of such close approaches. In other words, unintentional interactions capture the conventional forms of collisions. Such interactions can occur during routine operations, with the growing number of objects in orbit from the decreasing cost of launch and pre-existing debris adding to the increased frequency of these interactions. The intentional/unintentional line matters analytically because each side sits under a different legal regime. Intentional acts, such as on-orbit servicing or rideshare operations, implicate contractual obligations with clearly delineated parties. Unintentional events run through the fault-based liability framework, where the inquiry centers on attribution, duty of care, the reasonable-operator standard, and compliance with mitigation guidance.¹⁰⁶ There are also clear policy implications that differ between the two types of interactions. Intentional interactions involve foreseeable operations at specific points in time and hence are more responsive to pre-planned preventive measures (e.g., approach protocols). Unintentional interactions are essentially unforeseeable accidents and require more general preventive measures that promote the overall safety conditions in orbit.

Within unintentional interactions, three sub-categories are arrayed along a spectrum of attribution and operational capacity: (1) collisions between two active spacecraft linked to identifiable operators, (2) interactions with an inactive spacecraft still attributable to a specific actor but unable to maneuver, and (3) interactions with space objects that cannot be traced to any operator at all. As one moves down the spectrum, the fault inquiry progressively weakens, initially as maneuver capacity erodes, then as attribution dissolves entirely. The block accordingly takes up the cross-cutting regime and its gaps first, before turning to each sub-category in sequence.

Commonly Applicable Governance Regimes

Hard Law

A major development in the regulation of unintentional on-orbit interactions is the FCC's new Part 100 framework. Announced in 2026, the new framework revamped the former Part 25 licensing and operational rules into a more comprehensive structure.¹⁰⁷ Part 100 requires applicants and licensees to support orbital-debris and space-safety certifications with orbital-debris mitigation plans, maintain collision avoidance contacts, share ephemeris and covariance data, operate consistent with their orbital-debris submissions, limit debris generation,

¹⁰⁶ Tort law applies to both kinds of interactions, but the possible unattributable nature of some unintentional collisions makes the analysis more difficult (e.g., how can you determine who breached a duty of care if you do not know who the operator is in the first place).

¹⁰⁷ FCC 2026 Order ¶¶ 24, 28.

maintain trackability, and respond to SSA conjunction warnings.¹⁰⁸ These requirements generally apply across different unintentional interaction subcategories. Noncompliance would trigger the FCC’s licensing and compliance tools, including administrative sanctions, temporary measures, and automatic termination.¹⁰⁹ The FCC also continues to consider further refinements to the Part 100 rules, including ephemeris-sharing requirements and additional orbital-debris mitigation measures.¹¹⁰

Industry Standard

Several industry standards apply broadly across unintentional interaction categories, establishing shared norms for conjunction assessment, probability-of-collision calculation, and debris mitigation that cut across all three interaction categories alike.

The American Institute of Aeronautics and Astronautics (“AIAA”) Satellite Orbital Safety Best Practices¹¹¹, jointly developed by major U.S. commercial operators, provides operational guidance on conjunction screening procedures, probability of collision (“Pc”) calculation methodologies, maneuver decision thresholds, and ephemeris sharing practices. It is the most operationally specific U.S. industry standard currently available and functions as the closest approximation to a shared commercial standard of care across unintentional interaction scenarios.

The 2023 NASA Spacecraft Conjunction Assessment and Collision Avoidance Best Practices Handbook (“NASA Handbook”)¹¹² establishes NASA’s internal standards for conjunction assessment and avoidance maneuver decision-making, and it is publicly available as a reference baseline for commercial operators. While binding only on NASA missions, it is widely treated as an authoritative technical reference and informs what reasonable conjunction assessment practice looks like across the industry.

The 2019 ODMSP¹¹³ operationalize debris mitigation norms for U.S. government missions and serve as the domestic technical baseline that the FCC’s orbital debris mitigation rules for commercial operators reference and incorporate by analogy.

Finally, similar to intentional interaction operations, bilateral and multilateral contracts and coordination agreements between operators represent an emerging category of

¹⁰⁸ FCC 2026 Order, Appendix A, §§ 100.111, 100.201(a)(1)(ii), 100.201(c), 100.260(a)(1), 100.260(e), 100.261(a), 100.261(b).

¹⁰⁹ FCC 2026 Order ¶ 25.

¹¹⁰ FCC 2026 Order ¶¶ 343–44, 372, 377–79.

¹¹¹ American Institute of Aeronautics and Astronautics, *Satellite Orbital Safety Best Practices 3.0* (Reston, VA: AIAA, 2026),

<https://aiaa.org/2026/05/18/aiaa-amazon-leo-eutelsat-iridium-and-spacex-release-reference-guide-satellite-orbital-safety-best-practices-3-0/>.

¹¹² Frederic J. Krage, *NASA Spacecraft Conjunction Assessment and Collision Avoidance Best Practices Handbook*, NASA/SP-20230002470 Rev. 1 (Washington, DC: National Aeronautics and Space Administration, Office of the Chief Engineer, 2023), <https://ntrs.nasa.gov/citations/20230002470>.

¹¹³ U.S. Government, *Orbital Debris Mitigation Standard Practices*, November 2019, https://orbitaldebris.jsc.nasa.gov/library/usg_orbital_debris_mitigation_standard_practices_november_2019.pdf.

self-governance instruments with a potential liability function. Operators often enter into written coordination agreements, such as memoranda of understanding governing conjunction response procedures or service agreements specifying maneuver notification obligations. These instruments can potentially establish a workable duty-of-care baseline that regulatory frameworks currently leave undefined and may provide the most tractable near-term liability anchor for third-party harm claims.

Government Infrastructure

The U.S. currently offers spacecraft operators valuable SSA data and conjunction data messages (“CDMs”) for no cost through Space-Track.¹¹⁴ This service, operated by the 18th Space Defense Squadron (“18 SDS”) of the U.S. Space Force, uses a combination of ground-based radar stations and operator-submitted ephemeris data to build a catalog of space objects and position estimates.¹¹⁵ Each detected object is given a unique Satellite Catalog number that can be used for identification and classification.¹¹⁶ Unlike the United Nations Office for Outer Space Affairs satellite registry, Space-Track individually monitors all detectable pieces of debris including rocket bodies and pieces of destroyed spacecraft. This cataloged data is propagated to estimate the time of closest approach and probability of conjunctions between space objects.

While much of Space-Track’s data is publicly available, there are unique features available to spacecraft owners/operators (“O/O”) that are designed to improve safety and reduce unintentional interactions between space objects.¹¹⁷ Any registered O/O will receive CDMs via the Space-Track.org user interface or via email. Under Part 100, FCC licensees who receive a conjunction warning are now required to take all possible steps to assess and mitigate the collision risk, including contacting operators of any active spacecraft involved, sharing ephemeris data, and modifying spacecraft attitude or operations as needed.¹¹⁸ For FCC licensees, submitting ephemeris and covariance data (to the 18 SDS and FCC-identified SSA systems) is now mandatory.¹¹⁹ The provision of ephemeris data can substantially improve the accuracy of the tracked object. One research paper found that Space-Track’s estimated position varies with operator-derived position by 0.86-2.06 kilometers on average.¹²⁰

¹¹⁴ Space-Track.org, “Documentation,” accessed August 1, 2026, <https://www.space-track.org/documentation>.

¹¹⁵ Frederic J. Krage, *NASA Spacecraft Conjunction Assessment and Collision Avoidance Best Practices Handbook*, NASA/SP-20230002470 Rev. 1 (Washington, DC: National Aeronautics and Space Administration, 2023), chs. 3 and 6; Combined Force Space Component Command, *Spaceflight Safety Handbook for Satellite Operators, Version 1.7* (April 2023), https://www.space-track.org/documents/SFS_Handbook_For_Operators_V1.7.pdf.

¹¹⁶ Combined Force Space Component Command, *Spaceflight Safety Handbook for Satellite Operators, Version 1.7* (April 2023), https://www.space-track.org/documents/SFS_Handbook_For_Operators_V1.7.pdf.

¹¹⁷ Combined Force Space Component Command, *Spaceflight Safety Handbook for Satellite Operators, Version 1.7* (April 2023), https://www.space-track.org/documents/SFS_Handbook_For_Operators_V1.7.pdf.

¹¹⁸ FCC 2026 Order, Appendix A, § 100.261(b).

¹¹⁹ FCC 2026 Order, Appendix A, § 100.201(c).

¹²⁰ Charles Constant, Santosh Bhattarai, and Marek Ziebart, “Limitations of Current Practices in Uncooperative Space Surveillance: Analysis of Mega-Constellation Data Time-Series” (paper presented at Advanced Maui Optical and Space Surveillance Technologies Conference, 2023), <https://amostech.com/TechnicalPapers/2023/Poster/Constant.pdf>.

Owner/operators are able to designate their satellites as “public” or “private.”¹²¹ When a spacecraft is marked public, other O/Os have access to any operator-submitted ephemeris or maneuver data. A public designation will also add contact information to the “O/O directory,” which can be used to establish communication between operators in the event of a CDM between two active satellites. If a spacecraft is marked private, contact information and operator-submitted data will only be visible to 18 SDS, even in the event of a conjunction.

Moreover, the DoC is currently developing a new TraCSS system that is intended to facilitate better safety coordination and data-sharing between operators.¹²² It will eventually replace Space-Track entirely, but the timing for this transition has not been announced. TraCSS provides automatic CDMs to participating spacecraft operators every four hours. Proposed maneuvers can also be “screened” for future conjunctions before the actual maneuver. Like Space-Track, TraCSS uses data from the DoD, but it is also able to support constant data-sharing from commercial partners. Since this system is not yet functional, its influence on spacecraft operations remains to be seen.

Self-Governance

Self-governance across all unintentional on-orbit interaction categories operates through a consistent operational workflow. Operators receive conjunction alerts via CDMs, derived primarily from U.S. Space Surveillance Network data, and screen events against internally defined Pc thresholds. They then decide whether to maneuver using operator-specific systems (including proprietary tools such as Starlink collision avoidance system and Stargaze-type¹²³ conjunction assessment platforms, as well as commercial software), supported by SSA providers such as LeoLabs and Kayhan Space.¹²⁴ This is refined through ephemeris and covariance sharing to improve orbit determination accuracy, followed by direct operator coordination to avoid conflicting maneuvers, applied consistently across the three unintentional interaction categories.

Common Governance Gaps

Hard Law

U.S. hard law remains prevention-oriented with no corresponding post-collision liability or fault allocation instruments. Even the new Part 100 continues this pattern. It strengthens preventative obligations but still mediates responsibility through licensing rather than

¹²¹ Combined Force Space Component Command, *Spaceflight Safety Handbook for Satellite Operators, Version 1.7* (April 2023), https://www.space-track.org/documents/SFS_Handbook_For_Operators_V1.7.pdf.

¹²² U.S. Department of Commerce Office of Space Commerce, “Traffic Coordination System for Space,” accessed August 1, 2026, <https://space.commerce.gov/traffic-coordination-system-for-space-tracss/>.

¹²³ SpaceX, “Stargaze: SpaceX’s Space Situational Awareness System,” accessed August 1, 2026, <https://starlink.com/updates/stargaze>.

¹²⁴ LeoLabs, “Real-time Conjunction Alerts for Safety of Flight,” accessed June 30, 2026, <https://leolabs.space/conjunction-alerts/>; Kayhan Space, “About Us,” accessed August 1, 2026, <https://kayhan.space/about-us>.

enforceable operator-to-operator accountability.¹²⁵ The licensing process also remains limited to current and future operations, with no direct mechanism to address the reduction of existing debris already in orbit.¹²⁶

Moreover, there is no binding legal instrument addressing autonomous collision avoidance or liability where maneuvers are executed without human intervention, despite these systems directly determining conjunction outcomes. However, this again is a preventative measure which does not resolve the looming issue of liability attribution in the orbital environment.

Fault Attribution Under Existing Frameworks

The central liability gap is that neither the domestic tort system nor the Liability Convention's fault-based standard under Article III¹²⁷ maps cleanly onto harms arising from unintentional interactions. With the existing frameworks and standards, even if each operator executed maneuvers consistent with its FCC-certified procedures and its own internal safety standards, there can still be catastrophic consequences, including collision. The harm is produced not by any single negligent act, but by the structural interaction of three governance failures: (i) the absence of pre-maneuver notification requirements, (ii) catalog update latency, and (iii) incomplete SSA data-sharing. Under a conventional negligence analysis, a plaintiff must identify a defendant whose breach of a duty of care caused the harm. However, when each operator complied with all applicable regulatory requirements and no binding rule required the coordination that would have prevented the outcome, identifying that breach becomes deeply difficult. The FCC's orbital debris mitigation rules and the voluntary orbital best practices frameworks together define the current standard of practice, but neither establishes a duty of coordination between autonomous systems operated by different space operators.¹²⁸ The current framework can only result in outcomes where, when real harm occurs, there is a lack of a proper path to attribution or remedy.

Third-Party Harm

A related liability gap concerns innocent third parties. In some cases, an operator may have done everything correctly, including filing current ephemeris data, monitoring conjunction screening, and receiving no actionable warning, yet still suffer harm produced entirely by the interaction of two other operators' individually lawful decisions. Under domestic tort principles, a third-party plaintiff would need to establish that at least one of the maneuvering operators owed

¹²⁵ See e.g., FCC 2026 Order, Appendix A, §§ 100.260, 100.261.

¹²⁶ FCC 2026 Order ¶ 290.

¹²⁷ Liability Convention, art. III.

¹²⁸ See Mitigation of Orbital Debris in the New Space Age, 85 Fed. Reg. 52422, ¶¶ 19, 55 (Aug. 25, 2020) (concluding that “even though some of the rules we adopt in this Order may involve or relate to concepts of space situational awareness or space traffic management,” the FCC’s rules are limited to debris mitigation disclosure and “have not considered other activities related to space situational awareness and space traffic management”); see also International Institute of Space Law, *Balancing Innovation and Responsibility: International Recommendations for AI Regulation in Space* (Paris: International Institute of Space Law, 2024), 23, <https://iisl.space/wp-content/uploads/2025/10/Final-Report-of-the-Working-Group-on-Legal-Aspects-of-AI-in-Space.pdf> (noting “the absence of standardized frameworks for AI in space”).

it a duty of care and breached it.¹²⁹ However, when both operators complied with all applicable FCC requirements and no rule required pre-maneuver notification to nearby operators, that breach is difficult to identify. Joint and several liability doctrines might offer a partial remedy, but they presuppose that each defendant contributed a tortious act, which may not be the case. As LEO congestion increases, the probability that an avoidance maneuver by one operator creates new risk for a nearby third party grows directly with orbital density. This is not a marginal edge case, but a foreseeable and increasingly common consequence of the current operational environment that existing tort doctrine and regulatory frameworks are not structured to address.

Industry Standard

Similar to gaps found in current hard law, the existing industry standards share a common structural limitation: they are exclusively prevention-oriented. The AIAA Satellite Orbital Safety Best Practices, the NASA Conjunction Assessment Best Practices Handbook, the IADC Guidelines, and the ODMSP all address how operators should screen for conjunctions, calculate probability of collision, and execute avoidance maneuvers.¹³⁰¹³¹ None of them establish any liability framework, assign responsibility when a collision occurs despite compliance, or provide a mechanism for third-party victims to seek remedy. The result is a body of industry standards that governs the front end of the risk management process while leaving the back end entirely unaddressed. Contractual agreements between operators represent the one instrument category with potential liability function, but they are ad hoc, non-universal, and exist only where operators have independently negotiated them. There is no requirement that any operator enter into a coordination or liability agreement with any peer, meaning the vast majority of operator-to-operator relationships in LEO are governed by no instrument with liability implications at all.

Moreover, all of these instruments apply only to trackable objects. The AIAA best practices, NASA's Conjunction Assessment Risk Analysis ("CARA") procedures, and ODMSP are all premised on the availability of catalog data sufficient to generate a CDM.¹³² For objects below the tracking threshold of the U.S. Space Surveillance Network, currently roughly 10 centimeters in LEO, none of these standards provide actionable guidance because the conjunction cannot be detected in the first place.¹³³ This gap is most acute for the unintentional

¹²⁹ American Law Institute, *Restatement (Third) of Torts: Liability for Physical and Emotional Harm* §§ 3, 7(a) (2010).

¹³⁰ American Institute of Aeronautics and Astronautics, *Satellite Orbital Safety Best Practices 3.0* (Reston, VA: AIAA, 2026), <https://aiaa.org/2026/05/18/aiaa-amazon-leo-eutelsat-iridium-and-spacex-release-reference-guide-satellite-orbital-safety-best-practices-3-0/>.

¹³¹ Inter-Agency Space Debris Coordination Committee (IADC), *IADC Space Debris Mitigation Guidelines*, IADC-02-01, rev. 4 (2025), https://www.unoosa.org/res/oosadoc/data/documents/2025/aac_105c_12025crp/aac_105c_12025crp_9_0_html/AC1_05_C1_2025_CRP09E.pdf.

¹³² National Aeronautics and Space Administration, "CARA Overview," accessed August 1, 2026, <https://www.nasa.gov/cara/cara-services>.

¹³³ National Research Council, *Limiting Future Collision Risk to Spacecraft: An Assessment of NASA's Meteoroid and Orbital Debris Programs* (Washington, DC: The National Academies Press, 2011), <https://doi.org/10.17226/13244>.

“active spacecraft-inactive spacecraft” and “active spacecraft-space objects” interaction categories, but it also affects “active spacecraft-active spacecraft” scenarios where smaller secondary objects are involved.

Finally, none of the existing industry standards address autonomy in any meaningful way. The AIAA best practices and NASA Handbook were developed for human-in-the-loop conjunction assessment processes and assume that a human operator reviews a CDM, evaluates the probability of collision, and makes a maneuver decision. They provide no guidance on threshold parameters for autonomous avoidance systems, no standard for algorithmic decision logic, and no framework for evaluating whether an autonomous maneuver that contributed to a harmful outcome was consistent with reasonable practice. As autonomous avoidance becomes the operational norm for large constellation operators, the gap between what these standards address and what operators actually do will continue to widen.

Self-Governance

Self-governance gaps across all unintentional on-orbit interaction categories arise from uneven operator capability and inconsistent participation in coordination practices. Collision avoidance capability and operational maturity vary, with some operators relying entirely on external tools and lacking the capability to generate accurate ephemeris in house, and unclear CDM screening thresholds or undefined conjunction response protocols.¹³⁴ In addition, not all spacecraft are maneuverable, with limited propulsion and varying levels of autonomy constraining the ability to respond to conjunctions. Adoption of proprietary and commercial systems (e.g. Stargaze and LeoLabs) is also not uniform, leading to fragmented approaches to conjunction assessment. The lack of standardized or enforceable coordination or maneuver priority rules also results in inconsistent risk interpretation and response across operators. That being said, the FCC’s new Part 100 rules now require licensees to respond to conjunction warnings, though the rule does not prescribe specific decision thresholds or response protocols, leaving the substance of avoidance decisions to individual operators.¹³⁵

Government Infrastructure

Space-Track remains a great source of conjunction and SSA data. Beyond the new Part 100 obligations, best practices for using the platform are still not communicated clearly to all operators.¹³⁶ The Space-Track Handbook for space operators does not clearly state the increased risk for marking a spacecraft as “private” nor the importance of providing accurate ephemeris and maneuver data.¹³⁷ An O/O could easily choose the private option for their spacecraft without fully understanding the implications.

¹³⁴ See Space Sustainability Rating, “Collision Avoidance Capabilities,” accessed August 1, 2026, <https://spacesustainabilityrating.org/the-rating/modules-cola/>.

¹³⁵ FCC 2026 Order, Appendix A, § 100.261(b).

¹³⁶ As mentioned above, the FCC’s new Part 100 rules now require licensees to share ephemeris data with 18 SDS or a successor entity, and to maintain a 24/7 collision avoidance point of contact. See FCC 2026 Order, Appendix A, §§ 100.201(a)(1)(ii), 100.201(c).

¹³⁷ Combined Force Space Component Command, *Spaceflight Safety Handbook for Satellite Operators, Version 1.7* (April 2023), https://www.space-track.org/documents/SFS_Handbook_For_Operators_V1.7.pdf.

As more spacecraft adopt autonomous maneuvering systems, the Space-Track interface remains largely intended for human operators. There are a limited number of application programming interface (“API”) commands that can be sent to the Space-Track server, but with significant restrictions. For example, the API command to retrieve data about a specific conjunction can only be sent once per hour.¹³⁸ This infrequent data stream could prevent an autonomous system from reacting dynamically to multiple conjunction events. Operators who do not follow these API frequency limits can face an immediate account ban. New CDMs are also only generated every eight hours, which can significantly cut into the 72-hour closest-approach margin.¹³⁹

Space-Track’s internal data also has inherent limitations that result from its ground-based sensor network. When space objects are in close proximity—such as during deployment from a launch vehicle or operation of a tightly packed constellation—the ground radar cannot easily distinguish between different objects.¹⁴⁰ This limitation currently requires operators to identify their spacecraft from onboard sensor data, representing a period of significant operational uncertainty for spacecraft operators. Otherwise, it can take up to multiple weeks for Space-Track to build a more accurate tracking solution.¹⁴¹ As mentioned previously, Space-Track can only track objects larger than 10 centimeters,¹⁴² despite the presence of smaller debris that could still pose a risk to active spacecraft. It is currently unclear if TraCSS will improve upon any of these system-level limitations.

(1) Unintentional U.S. Private Spacecraft ↔ Spacecraft Interactions

Unintentional interactions between active spacecraft are among the most common on-orbit scenarios today. As the number of spacecraft continues to grow rapidly, 18 SDS issues on the order of thousands of CDMs per day, with operators managing hundreds of actionable close-approach alerts. When U.S. spacecraft operators receive a conjunction warning from 18 SDS, they are expected to take appropriate action to mitigate collision risk.¹⁴³ These responses can range from monitoring and dismissing sub-threshold events, to coordinating bilaterally with the other operator, to unilaterally executing a collision avoidance maneuver (“CAM”), whether

¹³⁸ Space-Track.org, “Documentation,” accessed August 1, 2026, <https://www.space-track.org/documentation>.

¹³⁹ Jaedong Seong, Okchul Jung, and Daewon Chung, “Accuracy Analysis of CDM for KOMPSAT Series Satellites” (paper presented at Advanced Maui Optical and Space Surveillance Technologies Conference, 2020), <https://amostech.com/TechnicalPapers/2020/Poster/Seong.pdf>.

¹⁴⁰ 18th Space Control Squadron, “Small Satellite Services & Collaboration: Working with the 18th Space Control Squadron (18 SPCS)” (pamphlet, August 2018), https://www.nasa.gov/wp-content/uploads/2018/01/ssa_services_pamphlet_aug18_conference_version.pdf.

¹⁴¹ 18th Space Control Squadron, “Small Satellite Services & Collaboration: Working with the 18th Space Control Squadron (18 SPCS)” (pamphlet, August 2018), https://www.nasa.gov/wp-content/uploads/2018/01/ssa_services_pamphlet_aug18_conference_version.pdf.

¹⁴² Theodore Kruczek, “Space Object Catalog,” KeepTrack, March 1, 2026, <https://keeptrack.space/space-terms/satellite-catalog>.

¹⁴³ The Aerospace Corporation, *2024 Space Safety Compendium: Collaborating for Sustainable Space Futures* (El Segundo, CA: The Aerospace Corporation, 2024), 33, https://aerospace.org/sites/default/files/2024-12/SSICompendiumBook_2024-12_FINAL.pdf (“Studies estimate thousands of conjunction alerts occurring per day, depending on the threshold violation criteria that is selected”).

impulsive or low-thrust, ground-commanded or fully autonomous.¹⁴⁴ In an increasingly autonomous environment, many CAMs are carried out with minimal or no human intervention, further complicating an already ambiguous framework for responsibility and fault attribution.

Illustrative Scenario

Two U.S. commercial spacecraft operators in LEO independently receive conjunction warnings flagging a close approach between their respective spacecraft. Both operators rely on autonomous onboard systems to assess and respond to the event, but neither system has visibility into the other's planned maneuver. Each spacecraft executes an avoidance burn within the same short window. However, their maneuvers are uncoordinated. The combined effect of the two burns places one spacecraft on a trajectory that intersects a third U.S. operator's spacecraft, which had no warning of the emerging secondary conjunction and no time to respond. The third spacecraft is destroyed, generating a debris field in a congested orbital shell shared by dozens of other operators.



(Figure 4. Illustrative scenario: unintentional interaction between two active spacecraft)

Specific Governance Instruments

The most structured governance instruments applicable to unintentional spacecraft-to-spacecraft interactions are bilateral coordination agreements and memoranda of

¹⁴⁴ Cynthia Wilson and Diana McKissock, “18 SDS Small Satellite Support” (paper presented at the 36th Annual Small Satellite Conference, 2022), <https://digitalcommons.usu.edu/cgi/viewcontent.cgi?article=5283&context=smallsat> (“18 SDS collects hundreds of thousands of metric observations daily from the U.S. Space Surveillance Network and calculates current and predicted orbital positions”).

understanding¹⁴⁵ negotiated directly between operators. NASA's CARA program operates under MOUs with commercial operators that define specific notification timelines, data-sharing obligations, and maneuver coordination procedures, creating a contractual framework that supplements the regulatory baseline and provides a clearer duty-of-care anchor for liability purposes. OSC has also entered into Cooperative Research and Development Agreements¹⁴⁶ with constellation operators to study and oversee automated collision avoidance systems, representing an emerging model for structured, agreement-based governance of autonomous maneuvering behavior. At the industry level, the Space Safety Coalition's *Best Practices for the Sustainability of Space Operations*¹⁴⁷, endorsed by operators including major U.S. commercial constellation operators, recommends direct operator-to-operator coordination, pre-maneuver notification, and ephemeris sharing as standard practice for conjunction response. These instruments do not rise to the level of binding regulation, but where adopted, they establish sufficiently concrete operational expectations to inform a negligence standard of care in civil litigation.

Specific Governance Gaps

The governance gaps in this interaction category operate at two levels: (i) prevention gaps (existing instruments fail to require coordination before a conjunction occurs), and (ii) liability gaps (responsibility fails to be assigned after harm results). Autonomy cuts across both levels and is addressed separately below.

Prevention Gap: Pre-Maneuver Notification

When two U.S. commercial operators independently plan and execute avoidance maneuvers in response to the same CDM, neither is required by any binding rule to notify the other operator, or any nearby third parties, before execution. The absence of a pre-maneuver notification obligation means that a third operator sharing the same congested orbital shell has no opportunity to update its own conjunction screening and identify an emerging secondary close approach before another satellite's maneuver creates one. The 2021 Starlink-OneWeb conjunction, which was resolved through direct email coordination between the two operators, illustrates that advance notification is both possible and effective when communication channels exist and operators are willing to use them.¹⁴⁸ However, the current reliance on ad hoc bilateral

¹⁴⁵ M.D. Hejduk et al., "Conjunction Assessment and Deconfliction Paradigm for Co-located Satellite Constellations with On-Spacecraft 'Autonomous' Flight Dynamics Control" (paper presented at the Advanced Maui Optical and Space Surveillance Technologies Conference, 2023), <https://amostech.com/TechnicalPapers/2023/Conjunction-RPO/Hejduk.pdf>.

¹⁴⁶ U.S. Department of Commerce Office of Space Commerce, *Let's Talk Space Traffic Coordination* (Washington, DC: U.S. Department of Commerce, July 2024), <https://www.space.commerce.gov/wp-content/uploads/Lets-Talk-Space-Traffic-Coordination-Office-of-Space-Commerce-July-2024.pdf>.

¹⁴⁷ Space Safety Coalition, *Best Practices for the Sustainability of Space Operations*, version 2.38 (Space Safety Coalition, May 2024), https://spacesafety.org/wp-content/uploads/2024/05/SSC_Best_Practices_for_Space_Operations_Sustainability_v2.38.pdf.

¹⁴⁸ Joey Roulette, "OneWeb, SpaceX Satellites Dodged a Potential Collision in Orbit," The Verge, April 9, 2021, <https://www.theverge.com/2021/4/9/22374262/oneweb-spacex-satellites-dodged-potential-collision-orbit-space-force>.

goodwill between operators also reveals a fundamental lack of coordination mechanisms that compel U.S. operators to notify even a domestic peer before maneuvering.

Prevention Gap: Bilateral Autonomous Avoidance

As autonomous orbital operations become more prevalent, the most structurally novel prevention gap is what may be called the bilateral autonomous avoidance problem. When two U.S. commercial operators each execute autonomous avoidance maneuvers independently within the same conjunction window, the outcome depends on the interaction of two decision systems with no visibility into each other's plans. Neither operator acted incorrectly by its own standards. Nonetheless, the harmful outcome produced by their combined maneuvers was not the product of any individual error, but of the interaction between two individually rational responses. This failure mode is unique to the operational context in which both spacecraft are maneuverable and both are operating autonomously. No existing domestic governance framework addresses it directly. FCC's new Part 100 requires operators to respond to conjunction warnings and share ephemeris for planned maneuvers, but it says nothing about coordination between autonomous avoidance systems operated by different operators.¹⁴⁹

Governance Gaps: Autonomy

As the bilateral autonomous avoidance problem shows, autonomy does not only complicate the governance picture, but also structurally undermines the underlying enforcement logic of governance instruments. FCC's Part 100 requires conjunction-warning response but sets no binding standard for the design, threshold parameters, or decision logic of autonomous avoidance systems.¹⁵⁰ Space Policy Directive-3¹⁵¹ calls for the development of space traffic management norms but operates at a human policy timescale wholly mismatched to the operational timescales in which autonomous systems execute maneuvers. Neither instrument reaches the internal design choices of an onboard avoidance algorithm. In fact, no existing domestic instrument, binding or voluntary, establishes a standard against which either operator's autonomous avoidance algorithm could be evaluated as negligent or compliant. One operator may use a Pc threshold of 1/10,000 whereas another may use 1/1,000.

The liability question that follows is equally unresolved. When the causal chain from design choices to collision outcome passes through multiple autonomous decision nodes operated by different U.S. licensees, fault attribution under domestic tort doctrine faces a threshold problem: there is no codified regulatory standard of care for autonomous avoidance system design against which a negligence claim can be anchored. A court assessing reasonable algorithmic design would have no statutory benchmark, no binding agency rule, and no industry standard carrying legal weight. There are only voluntary best practices whose adoption is unverifiable and whose deviation carries no legal consequence.

A further dimension of this problem is algorithmic explainability. Even where a plaintiff can identify the autonomous system that executed a harmful maneuver, reconstructing why that

¹⁴⁹ FCC 2026 Order, Appendix A, §§ 100.201(c), 100.261(b).

¹⁵⁰ FCC 2026 Order, Appendix A, § 100.261(b).

¹⁵¹ National Space Traffic Management Policy, 83 Fed. Reg. 28969 (June 18, 2018).

system made the specific decision it did, and whether that decision was reasonable, may be technically and legally fraught. Modern onboard avoidance algorithms may incorporate real-time sensor fusion, probabilistic trajectory propagation, and learned behavioral parameters that produce maneuver decisions that are neither fully deterministic nor easily re-constructable after the fact.¹⁵² Unlike a human-commanded maneuver, an autonomous maneuver may be the product of a decision boundary that was never explicitly programmed but instead emerged from training data or optimization processes. This creates a structural explainability gap: the operator may be genuinely unable to produce a complete causal account of why its system chose a particular burn magnitude and direction at a particular moment. Compounding this, the specific maneuver executed in any given conjunction reflects the system's response to a novel set of real-time conditions that differ from test parameters. A court or regulator will struggle to evaluate whether the algorithm behaved reasonably. For instance, it may struggle to compare the system's response to its pre-approved set of decisions and industry standards. Existing tort doctrine, built around the assumption that human actors can explain and justify their choices, may not be equipped to handle autonomous decision systems.

Analysis: Formalization and Innovation–Regulation Trade-off

Pre-Maneuver Notification

The pre-maneuver notification gap presents a more complex innovation-regulation trade-off. Soft law recommends notification, and while Part 100 requires ephemeris updates for planned maneuvers, no binding rule requires advance notification to other operators before executing a conjunction-avoidance maneuver.¹⁵³ However, a hard pre-maneuver notification requirement with a fixed lead time could conflict with the operational timescales of autonomous avoidance systems. When a spacecraft executes a rapid avoidance maneuver autonomously, a requirement to notify other operators in advance may not be achievable. Locking in a notification window that is feasible for human-operated systems but not for autonomous ones would create a perverse incentive to slow down avoidance decision-making or to disable autonomous capability entirely. Both of these may lead to worse outcomes than the current gap.

The appropriate response therefore sits around the middle of the formalization spectrum. One example is an industry-agreed post-maneuver notification requirement within a defined window, combined with a requirement to file updated ephemeris immediately following any maneuver. Voluntary compliance with this standard by major U.S. operators could be treated as a safe harbor in any subsequent liability analysis, creating a compliance incentive without mandating a specific timeline that may become technically obsolete.

¹⁵² Frederic J. Krage, *NASA Spacecraft Conjunction Assessment and Collision Avoidance Best Practices Handbook*, NASA/SP-20230002470 Rev. 1 (Washington, DC: National Aeronautics and Space Administration, Office of the Chief Engineer, 2023), <https://ntrs.nasa.gov/citations/20230002470>; Policy Lab team's discussions with commercial spacecraft operators.

¹⁵³ FCC 2026 Order, Appendix A, § 100.201(c).

Bilateral Autonomous Avoidance

At its core, the bilateral autonomous avoidance problem arises from the absence of a coordination mechanism between autonomous systems operated by different operators. In the near term, law must work around this constraint primarily by improving the background conditions (e.g., catalog completeness and post-maneuver notification) that allow each operator's autonomous system to make better-informed independent decisions. Improving these conditions reduces the probability of the bilateral avoidance failure mode even in the absence of direct inter-operator coordination.

In the medium term, this gap points toward the need for a more formalized regulation: a common protocol specifying which spacecraft yields in a conjunction, analogous to maritime rules of the road. Such a convention would function as a coordination device that both sides apply independently, reducing the probability that individually rational maneuvers interact destructively.

Liability Gaps

The inability of existing frameworks to assign responsibility when damage results from the structural interaction of governance failures rather than from a single operator's individually tortious act is the hardest to address through incremental reform. The Liability Convention was designed for an era of discrete, government-operated missions and has never been updated to address commercial constellations executing thousands of autonomous maneuvers per month. Domestically, tort doctrine faces the same structural difficulty: where no individual operator breached a binding duty, negligence analysis has no anchor.

A strict liability regime for debris-generating collisions in LEO would bypass the attribution problem entirely by assigning liability regardless of fault. The innovation-regulation trade-off for strict liability is contested, as operators argue it could create perverse incentives to avoid maneuvering altogether. A more calibrated approach could be a rebuttable presumption of liability against operators who failed to meet minimum data-sharing and notification standards, preserving fault inquiry where operators met baseline requirements while providing a pathway to recovery where they did not.

(2) Unintentional U.S. Private Spacecraft ↔ Inactive Spacecraft & Trackable Space Objects

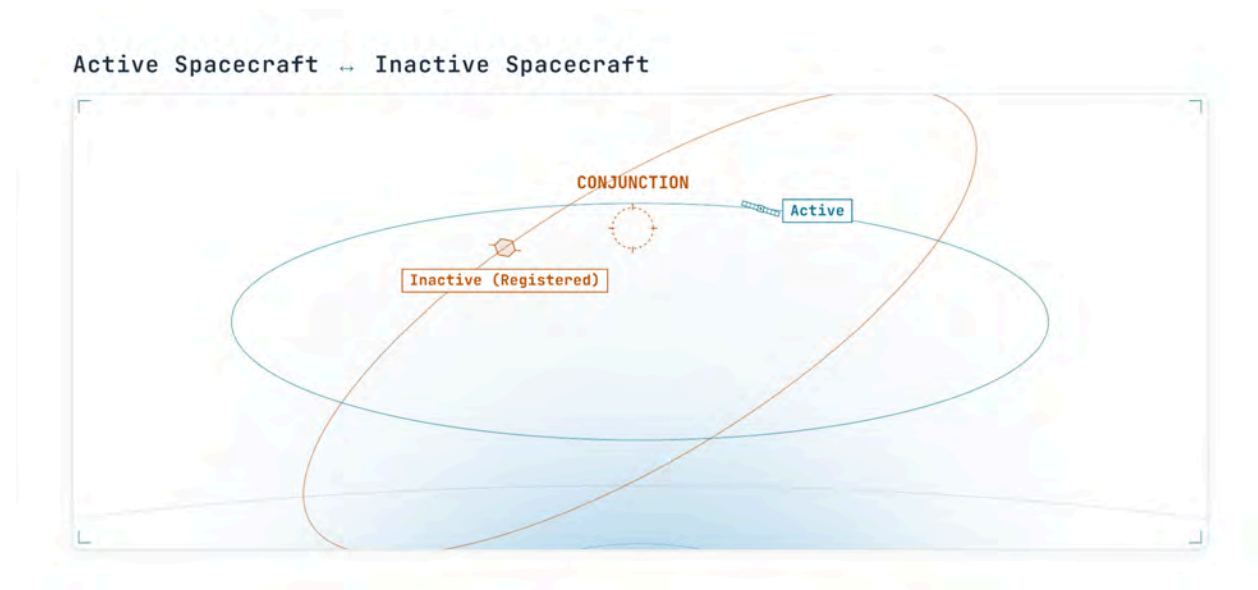
There are currently about 40,000 to 55,000 pieces of inactive spacecraft and trackable space objects in Earth's orbit. Although these objects are not as dynamic as active satellites, they pose a significant risk to future space operations. Between 2016 and 2021, Space-Track reported 3 million conjunction events between a payload and debris¹⁵⁴. The probability of collision for

¹⁵⁴ Daniel Moomey, Rachael Falcon, and Arbab Khan, "Trending and Analysis of Payload vs. All Low Earth Conjunction Data Messages Below 1,000 km, from 2016 through 2021" (paper presented at the Advanced Maui

these active satellite-debris conjunctions can be on the order of 0.05%, which is much higher than that of most satellite-satellite conjunctions.¹⁵⁵ In a landscape without clear rules of the road for maneuvering and collision avoidance, a catastrophic collision between a known space object and an active spacecraft is a very real possibility.

Illustrative Scenario

A U.S. spacecraft constellation is operating in LEO. Their onboard autonomous collision avoidance system is sending and receiving ephemeris data with other active spacecraft. The system detects a close approach with another communication spacecraft in about 42 hours. The constellation spacecraft indicates to the communication spacecraft that it will change altitude to resolve the conjunction. The maneuver is performed, but the new orbit places the constellation satellite on a collision course with a small inactive “cubesat.” The onboard sensors are unable to detect the small cubesat. The cubesat is cataloged on Space-Track, but a new CDM will not be generated in another 4 hours. At very close range, the onboard sensors detect the cubesat, but they cannot estimate its trajectory. The system tries to downlink to Space-Track but is prevented by the API call limit. The cubesat collides at hypervelocity with one of the constellation spacecraft and cascades into another spacecraft in the constellation, generating over 3,000 pieces of debris.



(Figure 5. Illustrative scenario: unintentional interaction between an active spacecraft and an inactive registered spacecraft)

Optical and Space Surveillance Technologies Conference, 2022),
<https://amostech.com/TechnicalPapers/2022/Poster/Moomey.pdf>.

¹⁵⁵ S. Le May, S. Gehly, B. A. Carter, and S. Flegel, “Space Debris Collision Probability Analysis for Proposed Global Broadband Constellations,” *Acta Astronautica* 151 (2018): 445–55.

Specific Governance Instruments

As of 2022, the FCC requires that all LEO operators dispose of inactive spacecraft no later than five years after the mission ends. Operators who violate this rule have been fined about \$150,000.¹⁵⁶ This indicates that the Federal Government is willing to hold U.S. producers of orbital debris accountable. This could also be useful for establishing “fault” in a collision. For instance, if an inactive spacecraft was not deorbited according to FCC regulations and collides with another active U.S. spacecraft, the inactive spacecraft should be at least partially liable for the collision due to the clear violation of a safety-critical regulation.

Specific Governance Gaps

Prevention: Limitations of Current On-Orbit Debris Sensing

Many spacecraft operators are beginning to develop their own detection capabilities using onboard sensors. A large number of inactive spacecraft and space objects are currently not detectable without data from a cataloging system like Space-Track. Most notably, Stargaze created by SpaceX boasts impressive capabilities for data sharing that can prevent active spacecraft to active spacecraft collisions.¹⁵⁷ However, according to several industry experts, Stargaze in its current form does not represent an adequate “one-stop SSA shop” for operators.¹⁵⁸ SpaceX is currently working to improve the capabilities of its sensor suite to detect more objects without outside data. In the meantime, this advanced system still needs to communicate with Space-Track or TraCSS to mitigate conjunctions with space objects. This exposes such a system to various governance gaps discussed above. For example, there is currently no hard law that requires spacecraft operators to demonstrate their guidance, navigation and control (“GNC”) system is robust enough to avoid debris of a certain size.

Prevention: Limitations of Ground-Based Debris Tracking

Despite using the “fairly robust” SSN created by the DoD, civilian spacecraft operators have noted significant gaps in Space-Track’s capabilities.¹⁵⁹ For example, it can take several days for spacecraft to be identified after launch. Space-Track also has substantial errors of up to 50 kilometers in determining the position of inactive spacecraft and space objects.¹⁶⁰ Third-party SSA operators like LeoLabs sell a product that specifically addresses these gaps. Using a

¹⁵⁶ Space Innovation; Mitigation of Orbital Debris in the New Space Age, 89 Fed. Reg. 65217 (Aug. 9, 2024) (codified at 47 C.F.R. pts. 5, 25, and 97)

¹⁵⁷ SpaceX, “Stargaze: SpaceX’s Space Situational Awareness System,” accessed August 1, 2026, <https://starlink.com/updates/stargaze>.

¹⁵⁸ Theresa Hitchens, “SpaceX Unveils ‘Stargaze’ Space Tracking System,” Breaking Defense, January 30, 2026, <https://breakingdefense.com/2026/01/spacex-unveils-stargaze-space-tracking-system/>.

¹⁵⁹ Shaun Waterman, “Space Traffic Management’s Tricky Future: Smaller Satellites, More Threats,” Air & Space Forces Magazine, July 23, 2025, <https://www.airandspaceforces.com/space-traffic-management-future-smaller-sats-more-threats/>.

¹⁶⁰ Charles Constant, Santosh Bhattarai, and Marek Ziebart, “Limitations of Current Practices in Uncooperative Space Surveillance: Analysis of Mega-Constellation Data Time-Series” (paper presented at the Advanced Maui Optical and Space Surveillance Technologies Conference, 2023), <https://amostech.com/TechnicalPapers/2023/Poster/Constant.pdf>.

proprietary radar system and software stack, they offer more accurate position vectors and more frequent CDMs.¹⁶¹ If Space-Track or TraCSS seeks to offer an improved SSA service, it would directly compete with LeoLabs and could potentially lead to industry pushback.

Liability: Lack of Substantial Punishment for Debris Producer

Although operators who do not deorbit their spacecraft within five years of mission completion violate the law, the fines given as punishment may not be substantial enough to make a difference. A fine of about \$150,000 is a small fraction of the total cost needed to build a functional spacecraft. Additionally, investing the labor of a GNC engineer for a year could easily surpass the value of the fine, and an operator may choose to just internalize the fine as a “cost of business.” There is no unified liability law or even industry standard that advocates for debris producers to be considered at fault for any collision involving that debris.

Analysis: Formalization and Innovation–Regulation Trade-off

Regulators are often wary of changing the status quo in the space environment, fearing that policy changes will stifle innovation or require unreasonable political action. However, FCC’s new Part 100, Space-Track, and TraCSS already offer a strong foundation to solve many of the gaps identified above. There may be no need to create a new governmental board or propose a new statute for the time being.

Moving forward, industry standards related to data-sharing and debris generation should be formalized into U.S. hard law and enforced via SSA platforms like TraCSS. Policy revisions should signal to operators that the U.S. government is invested in promoting orbital safety to preserve the utility of space for generations to come.

(3) Unintentional U.S. Private Spacecraft ↔ Untrackable Space Objects

Unintentional interactions between spacecraft and untrackable space objects represent another category of conjunction events. As debris from fragmentation events increases, operators will face a growing number of potential collisions, many of which may not be fully trackable with ground-based radar systems. Because only the active spacecraft can take action to mitigate these risks, operators may need to consider measures to reduce both the likelihood and potential impact of such collisions on their satellites. This analysis focuses on untrackable debris, generally corresponding to space objects smaller than ten centimeters which cannot be reliably detected or monitored.¹⁶² Current technology means collisions with such objects occur without warning and are typically excluded from conjunction assessment systems, removing the possibility of avoidance maneuvers. The non-traceability of these objects also makes attribution and responsibility practically unachievable. Moreover, collisions can generate additional objects,

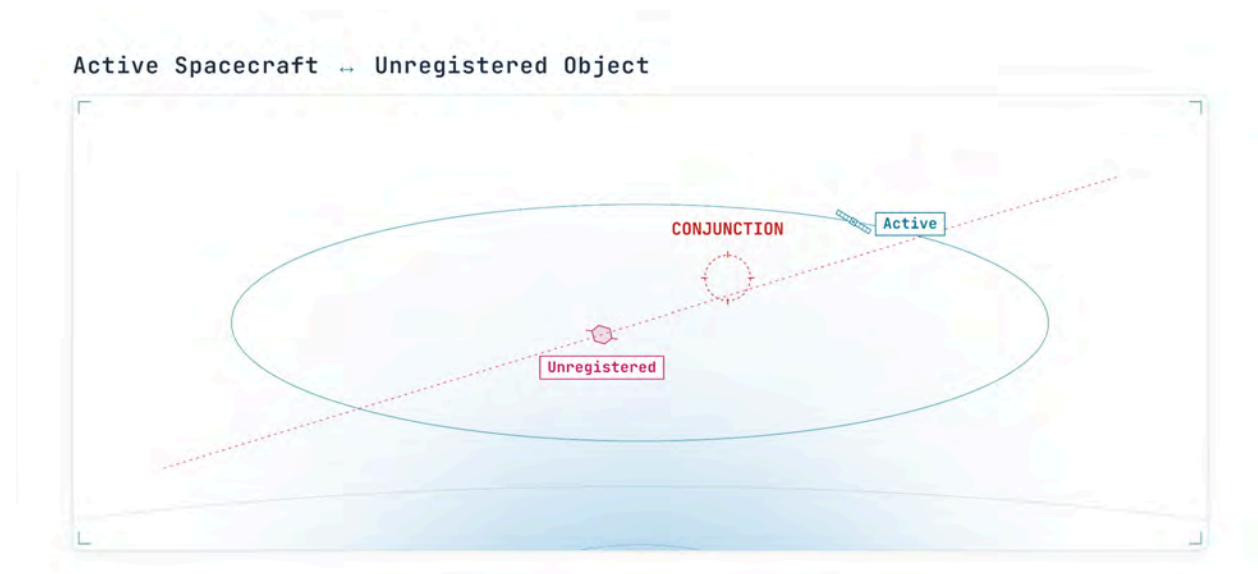
¹⁶¹ LeoLabs, “Space Traffic Management,” accessed August 1, 2026, <https://leolabs.space/space-traffic-management/>.

¹⁶² The Aerospace Corporation, “Space Debris 101,” accessed August 1, 2026, <https://aerospace.org/article/space-debris-101>.

including secondary fragments and spallation from spacecraft surfaces, further increasing the long-term risk to other operators.¹⁶³

Illustrative Scenario

A U.S. commercial operator deploys a small Earth observation spacecraft in LEO, operating nominally within its assigned orbit without onboard propulsion or maneuvering capability. The spacecraft is struck by an untracked debris fragment, typically on the order of a few centimeters, which is not cataloged and therefore generates no conjunction warning. Traveling at hypervelocity, the fragment strikes the spacecraft's primary payload, rendering it mission-defunct and creating even more debris. The source of the fragment cannot be identified or attributed to any specific spacecraft or operator, leaving no clear basis for fault or responsibility despite the direct physical damage.



(Figure 6. Illustrative scenario: unintentional interaction between an active spacecraft and an unregistered space object)

Specific Governance Instruments

The relevant U.S. hard law instrument is the FCC's new Part 100, which carries forward the collision-risk requirements previously stipulated under 47 C.F.R. Part 25.¹⁶⁴ Specifically, license applicants must certify that the probability of their spacecraft becoming a source of debris through collision with small debris or meteoroids is 0.01 (1 in 100) or less.¹⁶⁵ This requirement treats untracked space objects as part of the general background collision risk that operators must

¹⁶³ European Space Agency, "Hypervelocity Impacts and Protecting Spacecraft," ESA Space Safety, accessed August 1, 2026, https://www.esa.int/Space_Safety/Space_Debris/Hypervelocity_impacts_and_protecting_spacecraft.

¹⁶⁴ FCC 2026 Order ¶ 76.

¹⁶⁵ FCC 2026 Order, Appendix A, § 100.111(d)(2)(vi).

account for during spacecraft design and mission planning. Part 100's operational obligations (e.g., conjunction-warning response, ephemeris sharing, trackability) all presuppose that the relevant object is detectable.¹⁶⁶ For untrackable debris, the regulation does not impose specific obligations regarding detection, avoidance, or attribution once the spacecraft is in orbit.

Specific Governance Gaps

Prevention gaps

Existing instruments do not govern interactions with untrackable space objects. As discussed, FCC debris mitigation rules operate at the design and licensing stage and focus on limiting future debris generation rather than managing existing debris. Untrackable space objects also fall beyond the scope of SSA operational systems. Hence, in practice, no mechanism exists to predict, detect, or avoid such collisions.

Liability Gaps

Existing instruments also do not meaningfully govern what follows after conjunctions with untrackable space objects. Current frameworks rely on attribution to specific actors and fault analysis, neither of which can be established for untracked space objects. If the collision generates additional fragments, which is likely at hypervelocity, responsibility for those fragments becomes even murkier. In practice, this means the operator absorbs the loss, with risk internalized through insurance (if even available in the first place) or design trade-offs.¹⁶⁷

Dependent Factor: Probability of Collision

The significance of the aforementioned governance gaps depends on the underlying likelihood of collision. At the individual spacecraft level, the risk remains relatively low in absolute terms, though it is increasing and very difficult to quantify precisely. Debris environment models carry significant uncertainty given the limited observational data on the sub-10 cm population, and published probability estimates should be treated directionally rather than as precise predictions. Nevertheless, available modeling suggests that the risk is not negligible. Le May et al. estimated a cumulative collision probability with untrackable debris of approximately 12.4% over ten years for a single failed satellite within a large constellation.¹⁶⁸ While such figures are highly model-dependent, they illustrate that even relatively low individual probabilities can accumulate across increasingly congested orbital environments.

What is clear is that the risk is not uniform. It varies considerably by spacecraft type, altitude, and operator capability. Large constellation operators typically deploy maneuverable satellites with active avoidance capabilities and the resources to invest in debris resilience, making untrackable debris a manageable operational risk addressed through design choices and

¹⁶⁶ FCC 2026 Order, Appendix A, §§ 100.261(a), 100.261(b).

¹⁶⁷ European Space Agency, "Hypervelocity Impacts and Protecting Spacecraft," ESA Space Safety, accessed August 1, 2026, https://www.esa.int/Space_Safety/Space_Debris/Hypervelocity_impacts_and_protecting_spacecraft.

¹⁶⁸ S. Le May, S. Gehly, B. A. Carter, and S. Flegel, "Space Debris Collision Probability Analysis for Proposed Global Broadband Constellations," *Acta Astronautica* 151 (2018): 445–55.

mission trade-offs. Active avoidance, however, only addresses trackable objects. In 2022, NASA estimated that 500,000 debris objects between 1–10 cm in LEO remain largely untrackable¹⁶⁹ and are therefore outside the reach of current collision avoidance systems. For well-resourced operators, this residual risk can often be absorbed through shielding, redundancy, and constellation architecture. Smaller operators deploying non-maneuverable spacecraft frequently lack such options, making them simultaneously the most physically vulnerable to untrackable debris and the least equipped to manage that exposure privately.

Existing instruments do not meaningfully differentiate between these cases, and no current instrument sets design standards calibrated to operator capacity. The governance question is therefore not whether the risk justifies broad intervention, but whether the existing framework adequately addresses the operators for whom untrackable debris poses the most serious and least manageable threat.

Autonomy

Autonomy does not fundamentally alter this analysis. While advances in autonomous collision avoidance improve responses to trackable objects, they depend on the same underlying detection capabilities.¹⁷⁰ By definition, untracked space objects cannot be observed in advance, so no decision, manual or automated, can be made beforehand. Autonomy therefore does not resolve the prevention or liability constraints in this interaction category.

Analysis: Formalization and Innovation–Regulation Trade-off

These gaps do not arise from a lack of governance instruments, but from a mismatch between what regulation assumes and what the environment allows. Existing frameworks rely on traceability and predictability. In this interaction category, neither holds. Collisions with untracked space objects are not observable in advance, so problems arise for both traditional modes of prevention and liability attribution.

This leads us toward the more informal end of formalization. In practice, a collision with untrackable space objects is handled as an operational risk. Operators manage exposure through design choices, shielding limits, and mission trade-offs rather than through enforceable rules.¹⁷¹ Given that per-spacecraft collision probabilities remain relatively low, this approach is currently workable. Overall, there is a case for maintaining the status quo.

That said, the viability of the existing approach depends on how the risk of collision evolves. Collision probability is difficult to quantify precisely due to limited observation, but the

¹⁶⁹ NASA Orbital Debris Program Office, “Frequently Asked Questions,” accessed August 1, 2026, <https://orbitaldebris.jsc.nasa.gov/faq/>.

¹⁷⁰ Chaoxu Mu et al., “Autonomous Spacecraft Collision Avoidance with a Variable Number of Space Debris Based on Safe Reinforcement Learning,” *Aerospace Science and Technology* 149 (2024): 109131.

¹⁷¹ Leonard David, “New Space Debris Shield? Satellites and Astronauts Could Suit Up in Novel ‘Space Armor,’” *Space.com*, October 16, 2025, <https://www.space.com/space-exploration/satellites/new-space-debris-shield-satellites-and-astronauts-could-suit-up-in-novel-space-armor>.

trend is upward, driven by increasing object density in LEO.¹⁷² While the risk remains manageable at the level of individual spacecraft, it accumulates across constellations and over time. This creates a structural tension: a regime that functions under current conditions may become insufficient as collision probabilities increase, especially if collisions begin to generate secondary debris in a vicious cycle.

The trade-off is that imposing prescriptive requirements too early risks constraining a system that is already managing a low-probability risk as effectively as current technology allows. At the same time, leaving the regime entirely informal assumes that the risk remains bounded. Within this context, a more proportionate approach may be progressive formalization, where existing practices are stabilized and made more consistent without assuming full control of the environment. Stronger intervention becomes relevant only if the risk profile changes materially.

Policy Options

The governance gaps identified above within the unintentional interactions categories call for responses at different levels of formalization and on different timescales. The policy options below are organized by feasibility and urgency.

1. Enhance Space Situational Awareness and Transparency

1.1 Short Term: Ensure access to 24/7 collision avoidance contacts through Space-Track and TraCSS

The FCC's new Part 100 rules require licensees and market-access recipients to designate a collision avoidance contact who is authorized and capable of making operational decisions and is available on a 24/7 basis.¹⁷³ This requirement establishes an important baseline for operator availability, but its effectiveness will depend on compliance in practice. A remaining governance question is how regulators and SSA providers will ensure that designated contacts remain current, are actually monitored on a 24/7 basis, and respond promptly when time-sensitive coordination is required. Space-Track and TraCSS could support enforcement of this requirement by establishing mechanisms to verify contact information, document attempted communications, and identify repeated failures to respond during conjunction events. Such records could provide regulators with a basis for monitoring compliance and, where appropriate, taking enforcement action.¹⁷⁴

1.2 Short Term: Promote additional industry standard resources on Space-Track and TraCSS

The NASA Handbook is currently the only industry standard clearly visible on Space-Track. However, this document does not promote frequent data-sharing. Other industry

¹⁷² European Space Agency, "Hubble's Impactful Life Alongside Space Debris," April 30, 2020, https://www.esa.int/Space_Safety/Hubble_s_impactful_life_alongside_space_debris.

¹⁷³ FCC 2026 Order, Appendix A, § 100.201(a)(1)(ii).

¹⁷⁴ FCC 2026 Order ¶ 25.

standard documents such as the AIAA Satellite Orbital Safety Best Practices specifically mention why data-sharing improves safety. Additional industry standards should be directly accessible on Space-Track and TraCSS to make smaller operators aware of these practices.

1.3 Short Term: Establish minimum ephemeris and autonomy reporting standards

The FCC’s new Part 100 rules substantially address the previous gap in ephemeris sharing by requiring licensees and market-access recipients to submit accurate and timely ephemeris data for each spacecraft to the 18 SDS and to FCC-approved SSA providers.¹⁷⁵ The rules also require operators to provide propagated ephemeris and covariance information for planned maneuvers.¹⁷⁶ The FCC encourages operators in or below LEO to update ephemeris at least every eight hours, and operators above LEO at least every 24 hours, but does not make these reporting intervals mandatory.¹⁷⁷

In accordance with this new framework, the FCC should build on the Part 100 requirements by establishing a minimum reporting cadence, with more frequent or event-triggered updates where a maneuver materially changes a spacecraft’s predicted trajectory. An eight-hour minimum cadence for spacecraft in or below LEO would convert the FCC’s existing recommended reporting frequency into a binding baseline, establishing a more consistent foundation for sustainable orbital coordination practices. The FCC should also develop clear standards for data quality, interoperability among approved SSA providers, and the timely availability of submitted data for conjunction assessment. These measures would strengthen the informational foundation for collision avoidance without prescribing how operators must design or execute their maneuvering systems.

Separately, as autonomous collision avoidance becomes more common, regulators should consider requiring operators to disclose sufficient information about their collision avoidance criteria to permit meaningful safety oversight, including relevant probability-of-collision thresholds and the circumstances under which autonomous systems may initiate or decline a maneuver. This may come from the FCC or OSC as its mission-authorization authority develops. Such disclosure need not require publication of proprietary source code or detailed algorithms. Rather, it should provide regulators with enough information to evaluate whether an operator’s autonomous decision framework is consistent with reasonable collision avoidance practices and, following an incident, to assess whether the system operated as represented.

1.4 Medium Term: Create a “Good Standing” score on TraCSS for orbital operators

Since TraCSS is designed to promote operator data-sharing, there should be a quantifiable way to measure the accountability and safety of each operator. Each operator should be assigned a “Good Standing” score on TraCSS. Operators that consistently share accurate ephemeris data and announce maneuvers in advance would receive a higher score. Operators who do not respond to requests for contact after a CDM or do not share ephemeris data would receive a much lower score. This score could take many forms depending on what is most

¹⁷⁵ FCC 2026 Order, Appendix A, § 100.201(c)(1).

¹⁷⁶ FCC 2026 Order, Appendix A, § 100.201(c)(1).

¹⁷⁷ FCC 2026 Order ¶ 287.

feasible to implement. It could be given directly by the OSC or measured by reported violations from operators. The score would be valuable for other operators to understand how much risk they take on when operating in a region near certain other operators. In time, as this score becomes a trusted metric across the industry, it could potentially serve as a tool for evaluating liability in the event of a collision.

2. Accountability and Enforcement

2.1 Medium Term: Increase penalties for debris generation

If debris is trackable and identified as originating from a U.S. operator, a substantial fine should be imposed by the FCC, adjusting the size based on the egregiousness of the violation. This could work in conjunction with the proposed “Good Standing” score on TraCSS. The collected fines could be used to support the upkeep of TraCSS or other government infrastructure supporting SSA.

2.2 Long Term: Establish a rebuttable “Presumption of Liability” standard for sub-standard operators

The U.S. should explore whether domestic tort law can be developed to establish a rebuttable presumption of liability against operators who failed to meet minimum SSA participation and notification standards at the time of a conjunction, while preserving the fault inquiry for operators who did meet baseline standards. In conjunction with the statutory proposal, the rebuttable presumption would be weighed against any codified standard of care. If an operator failed to abide by the codified standard of care and subsequently injured another party, the assumption is that the operator’s failure to follow the statute caused the injury. Thus, the operator has the burden of proving they did not cause the tortious act.

This avoids the perverse incentives associated with full strict liability while providing third-party victims with a viable claims pathway when a collision was enabled by a failure to meet minimum data-sharing obligations. This presumption scheme is used in U.S. admiralty law via *The Pennsylvania Rule*.¹⁷⁸ While establishing causation through multiple autonomous decision nodes presents significant evidentiary complexity, the absence of any domestic remedy is itself a gap that does not require international action to begin addressing.

3. Structural Reforms for Orbital Governance

3.1 Medium Term: Establish a statutory On-Orbit Authorization Regime

Congress should create a new statutory regime that explicitly governs on-orbit activities. One of the biggest governance gaps is the lack of clear statutory authority for any government

¹⁷⁸ The Pennsylvania Rule provides that when a vessel violates a statutory rule intended to prevent collisions, a rebuttable presumption of causation arises against the offending vessel. To overcome the presumption, the violating party bears the burden of proving not merely that the violation probably did not contribute to the casualty, but that it could not have contributed. *The Pennsylvania*, 86 U.S. (19 Wall.) 125, 136 (1873).

agency to regulate on-orbit activities. Currently the FAA regulates launch and re-entry operations while the FCC regulates some orbital operations but only to the extent that they impact the telecommunications spectrum. While the FCC has expanded these requirements considerably through its new Part 100 rules, it has expressly grounded that expansion in its spectrum-licensing authority rather than establishing a general power over on-orbit conduct.¹⁷⁹ But these agencies' current statutory authority is not sufficient to govern more substantive on-orbit activities. No agency has explicit statutory authority to promulgate rules or enforce standards for on-orbit operations. Without this authority, courts could strike down an agency's exercise of authority over orbital operations as a violation of the Major Questions Doctrine.¹⁸⁰ Practically, an explicit statutory grant would allow funding and resources to go to the targeted agency and help create a pool of government orbital experts that can help effectively govern orbital operations. The statute could also codify any "rules of the road" and thus help tort liability adjudication. A statute like this could set the foundation for future governance of the space economy.

3.2 Long Term: Establish and enforce standards for domestic "Right-of-Way" protocols

The U.S. should establish a domestic right-of-way framework for autonomous avoidance maneuvers that lays down a common protocol specifying which spacecraft yields in a two-spacecraft conjunction. The exact protocol can be based on objective criteria such as constellation size, maneuver cost, or orbital altitude. Such a framework would function as a coordination device that operators apply independently, reducing the probability of coordination failures without requiring real-time communication. A useful parallel exists in the maritime domain: the Convention on the International Regulations for Preventing Collisions at Sea ("COLREGS") established a right-of-way framework that mariners apply independently without real-time coordination, and which maritime arbitration panels apply consistently in resolving liability disputes.¹⁸¹ The domestic equivalent is the Inland Navigation Rules Act of 1980, which codifies many of the COLREGS provisions.¹⁸² A domestic space right-of-way framework could function analogously, providing a de facto standard of practice that builds momentum toward broader international adoption. In the longer term, the U.S. should take the lead in advocating for an international space right-of-way convention.

¹⁷⁹ For example, in adopting the new "Variable Trajectory Space Station" category, the FCC deliberately chose "*Space Station*" over the proposed "Variable Trajectory *Spacecraft System*" to make clear that its focus is "on the station used for radiofrequency communications, rather than the spacecraft as a whole." FCC 2026 Order ¶ 29. The FCC further explained that it distinguishes "space station" from "satellite" and "spacecraft" to promote clarity "in the Commission's rules and in matters of statutory authority." FCC 2026 Order ¶ 32.

¹⁸⁰ An agency must identify clear congressional authorization for any claimed power to resolve a major question, *West Virginia v. EPA*, 597 U.S. 697, 721 (2022), and courts owe no deference to the agency's own statutory interpretation in making that determination, *Loper Bright Enters. v. Raimondo*, 603 U.S. 369, 412 (2024).

¹⁸¹ Convention on the International Regulations for Preventing Collisions at Sea arts. 15–17, Oct. 20, 1972, 28 U.S.T. 3459, 1050 U.N.T.S. 16.

¹⁸² See Inland Navigational Rules Act of 1980, Pub. L. No. 96-591, 94 Stat. 3415 (codifying navigation rules for inland waters of the U.S. substantially mirroring the COLREGS, originally at 33 U.S.C. §§ 2001–2038, rules subsequently recodified at 33 C.F.R. pt. 83 (2010)).

4. Monitoring the Risk Profile of Interactions with Untrackable Space Objects

In the near term, the risk of untrackable debris should continue to be managed by operators through design choices and mission trade-offs. This is appropriate while per-spacecraft collision probabilities remain relatively low, leading operators to invest in active avoidance and debris resilience, and existing instruments such as the five-year deorbit rule address the primary mechanism through which individual failures compound into systemic risk. Moreover, because the debris population of concern is largely untrackable, neither avoidance requirements nor liability mechanisms can operate effectively: operators cannot avoid objects they cannot detect, and responsibility for collisions is often difficult to establish. The status quo is therefore broadly workable under current conditions, particularly for operators with the resources and capabilities to manage residual exposure to untrackable debris.

Its viability depends on how the risk profile evolves. As object density increases, the concern shifts from individual impacts to cascading debris generation that existing mitigation guidelines have not reversed. If that changes materially, future intervention should focus on two areas. First, outcome-based design standards that improve resilience to untrackable debris, particularly for non-maneuverable spacecraft and operators with limited capacity to manage collision risk through avoidance. Second, improving the conditions under which avoidance becomes possible: investment in ground-based and space-based detection systems targeting smaller debris would progressively reduce the untrackable category, enabling more prescriptive avoidance requirements as the detectable size threshold decreases.

The approach should be one of progressive formalization tied to observable changes in risk rather than precautionary mandates imposed ahead of demonstrated need. While current collision probabilities do not justify broad intervention across all operators, future governance should pay particular attention to those actors for whom untrackable debris poses the most serious and least manageable threat.

Table 2. Proposed Measures for Unintentional Interactions

Proposal	Interaction Type	Key Actors	Time Horizon	Expected Impact	Cost	Political Feasibility	Technical Feasibility
Enhance Space Situational Awareness and Transparency							
1.1 Ensure access to 24/7 collision avoidance contacts through Space-Track and TraCSS	Active ⇌ Active	FCC; 18 SDS; DoC (OSC/TraCSS); operators	Short term	● Moderate: operationalizes the Part 100 24/7-contact rule so contacts stay current and responsive for time-sensitive coordination.	● Low: builds on the existing Part 100 requirement using Space-Track/TraCSS.	● Add-on to an already-adopted FCC rule.	● Requires new verification/logging mechanisms on Space-Track and TraCSS.
1.2 Promote additional industry-standard resources on Space-Track and TraCSS	Active ⇌ Active	DoC (OSC/TraCSS); 18 SDS (Space-Track); NASA; AIAA; operators	Short term	● Moderate: surfaces best-practice standards for smaller operators, but may be voluntary.	● Low: makes existing standards accessible on current platforms.	● Non-controversial; voluntary resources.	● Requires posting resources to Space-Track/TraCSS.
1.3 Establish minimum ephemeris and autonomy reporting standards	Active ⇌ Active	FCC; 18 SDS; OSC; FCC-approved SSA providers; operators	Short term	● High: creates an 8-hour cadence baseline and adds autonomy-decision disclosure for oversight.	● Low: administrative build-out on the existing Part 100 framework.	● Regulators favor transparency and operators largely share already, though a mandatory cadence adds some burden.	● Feasible though reporting cadence and autonomy disclosure vary by operator capability.
1.4 Create a “Good Standing” score on TraCSS for orbital operators	Active ⇌ Active	DoC (OSC/TraCSS); operators	Medium term	● Moderate: reputational incentive to share data and pre-announce maneuvers; complements penalties.	● Moderate: build and maintain a scoring system within TraCSS.	● Operators may resist public scoring/ranking.	● Feasible using TraCSS data, but requires defined, defensible metrics.
Accountability and Enforcement							
2.1 Increase penalties for debris generation	Active ⇌ Unregistered	FCC; operators	Medium term	● Moderate: deters debris-generating behavior and could fund SSA, but hinges on attribution and enforcement.	● Low: uses existing FCC enforcement; fines can fund TraCSS/SSA.	● Operators may resist fines.	● Depends on reliably attributing trackable debris to a U.S. operator.
2.2 Establish a rebuttable “Presumption of Liability” for sub-standard operators	Active ⇌ Active	U.S. Congress; U.S. courts	Long term	● Moderate: strong deterrent that realigns incentives, but corrective and dependent on enforcement.	● Moderate: developed via tort law/legislation.	● Contested: operators will likely resist the liability shift; requires legislative or judicial development.	● No technical barrier to the standard itself, though the main difficulty is the requisite evidence to prove causation.

Structural Reforms for Orbital Governance							
3.1 Establish a statutory On-Orbit Authorization Regime	Active ⇔ Active	U.S. Congress	Medium term	● High: closes the fragmented-authority gap with a comprehensive federal framework.	● Inexpensive to draft but requires extensive stakeholder coordination.	● Unclear whether a federal statute of this nature could pass in the current Congress.	● No inherent technical barriers.
3.2 Establish and enforce standards for domestic “Right-of-Way” protocols	Active ⇔ Active	OSC / FCC or industry	Long term	● Moderate: sets priority rules to reduce maneuver ambiguity, but domestic-only reach limits effect on foreign operators.	● Inexpensive to draft but requires extensive stakeholder coordination.	● Operators may disagree over maneuver priority; broad domestic consensus may be difficult.	● No inherent technical barriers.

Rating key: ● green marks the most favorable rating, ● red the least.

Cost: ● low ● moderate ● high

Political feasibility: ● high ● moderate ● low

Technical feasibility: ● high (least barriers) ● moderate ● low

Conclusion

This Policy Lab set out to evaluate how U.S. law governs interactions between objects in orbit. Contrary to what some may believe, the space governance regime is neither absent nor adequate. Across the six interaction categories mapped out above, we found that rules, whether hard law or “softer” industry standards, exist but are incomplete.

The FCC’s new Part 100 rules, adopted while this report was being finalized, close several of the gaps identified in the preceding parts, including mandatory ephemeris sharing and the provision of operator contact information. Of course, these rules only apply to FCC licensees, which leave out important foreign operators that fall beyond the scope of the FCC regime. Even among American operators, other governance gaps remain, such as liability and the standards surrounding autonomous operations.

In the near term, three sets of actors assume consequential roles. The FCC should continue the consultation process it has already opened and specify the operational details that Part 100 leaves open. This can begin with information disclosure requirements, such as the cadence at which ephemeris data must be reported. Across the executive branch, the more pressing question is creating an effective information distribution mechanism. The information reported to regulators, including the FCC, will only translate into useful data for collision avoidance when it reaches the operators who need it. Operators, for their part, are now subject to new obligations that were until recently voluntary. For them, compliance is the immediate task.

Action is warranted now precisely because the conditions that make governance difficult are still forming rather than settled. Orbital activity is poised to increase sharply, with competition intensifying both domestically and internationally. Under these circumstances, governance provides the stable backbone on which outer space development depends.

Appendix

Domestic Tort Law and Commercial Space Activities

As more capital and assets are launched into orbit, the risk of unintentional accidents rises. On-orbit assets are costly, and companies will rightfully want to be compensated for any losses. But the jurisprudence regarding on-orbit liability for tortious conduct is scant, if not nonexistent. To date, the only black letter law that deals specifically with on-orbit liability is the Liability Convention. The Liability Convention specifically and exclusively covers on-orbit liability disputes between nation states and their respective actors.¹⁸³ There is no mention of a liability scheme for purely domestic issues, such as those between parties of the same country of origin or launching state. Therefore, it will be up to domestic tort law to fill that gap and occupy the field entirely as the default dispute resolution mechanism for purely domestic issues.

The U.S. is the largest and most aggressive commercial space-faring country.¹⁸⁴ Private American space companies have been putting more assets into orbit than most countries.¹⁸⁵ Therefore, there is a good chance that if a collision or incident occurs between assets on-orbit, it will be between two American commercial space companies. To date, no one has brought a tort case into American courts regarding the collision of two objects in orbit, intentional or otherwise. Regardless, the American tort system may be the default system of adjudication for a claim between only American parties. This analysis seeks to shed light on how an on-orbit claim would work its way through American courts and highlight specific wrinkles in the legal analysis based on the intentionality of the conjunction, the level of autonomy used in each on-orbit object, and evidentiary challenges that parties will face in bringing and defending an on-orbit claim. For this analysis, we will look at California tort law specifically, as many major commercial space companies are incorporated in or have their principal place of business in California.¹⁸⁶ Therefore, there is a good chance that if an on-orbit tort claim gets into court, it will be in a court that applies California law.

¹⁸³ Liability Convention, art. VII.

¹⁸⁴ See Satellite Industry Association, “Historic Number of Launches Powers Commercial Satellite Industry Growth - Satellite Industry Association Releases the 28th Annual State of the Satellite Industry Report,” May 13, 2025, <https://sia.org/historic-number-of-launches-powers-commercial-satellite-industry-growth-satellite-industry-association-releases-the-28th-annual-state-of-the-satellite-industry-report/> (showing that at the end of 2024, American companies operated more than 70% of total on-orbit satellites).

¹⁸⁵ See Press Release, Federal Aviation Administration, *New Record for FAA-Licensed Commercial Space Operations, Aerospace Rulemaking Committee Launched to Update Licensing Rule* (Nov. 14, 2024), <https://www.faa.gov/newsroom/new-record-faa-licensed-commercial-space-operations-aerospace-rulemaking-committee> (showing Fiscal Year 2024 had a record 148 licensed space operations, up more than 30% from the previous year).

¹⁸⁶ See California Governor’s Office of Business & Economic Development, *California’s New Space Industry Task Force to be led by the Governor’s Office of Business and Economic Development* (2022), <https://business.ca.gov/californias-new-space-industry-task-force-to-be-led-by-the-governors-office-of-business-and-economic-development/> (reporting that California’s space industry generated over \$66 billion in economic activity per year and half a million jobs).

Domestic Tort Law May Be the Default

In the event of a collision between two American satellites or any dispute between American space companies, the default is domestic American tort law and, where applicable, contract law. The Outer Space Treaty states: “A State Party to the Treaty on whose registry an object launched into outer space is carried shall retain jurisdiction and control over such object, and over any personnel thereof, while in outer space or on a celestial body.”¹⁸⁷ While never formally adjudicated in court as granting American courts jurisdiction over American-only space disputes, the Treaty supports the idea that the U.S. maintains jurisdiction over American objects and personnel in space. This has not been challenged in the limited caselaw relating to outer space activities. While there has not been any tort case involving on-orbit collisions, there have been cases involving space-related activities.

In *Martin Marietta Corp. v. Intelsat*, the Martin Marietta Corporation, a Maryland corporation, filed a declaratory judgment against International Telecommunications Satellite Organization (“INTELSAT”), an international organization, seeking relief from a contractual obligation.¹⁸⁸ INTELSAT subsequently filed a counterclaim for negligence, negligent misrepresentation, gross negligence, and breach of contract, demanding approximately \$400 million. The contract stated that Maryland law would govern the contract.¹⁸⁹ This case was originally filed in the Federal District Court in the District of Maryland and was a mix of tort and contract claims. While this case involves a non-U.S. company, the procedural lessons remain applicable to US-only disputes.

The heart of the claim comes from the contract signed between Martin Marietta and INTELSAT. Martin Marietta was to launch one INTELSAT satellite into orbit via its Titan III rocket. After launch, the satellite failed to separate properly at the right time, and it failed to reach the correct orbit. The satellite was operationally useless and had to be rescued later by NASA. The case went to the Fourth Circuit Court of Appeals, where it was affirmed in part and reversed in part. Both sides ultimately settled, leaving some legal questions unanswered.

While this case is not necessarily binding legal precedent nationally, it does offer clues into how a court may rule on a case between two sophisticated parties.¹⁹⁰ First, the district court and appellate court were wary of attaching general tort duties to a contractual duty of care. The court reasoned that under Maryland law, such a duty would apply with respect to representations made in the contract to “protect peculiarly vulnerable parties.”¹⁹¹ In this case, both parties were large, commercially sophisticated entities with a wealth of experience in space activities. The court seemed wary about adding additional protections to such a contract. This decision shows that courts in the future, with regard to space activities, may be less willing to impose tort duties

¹⁸⁷ Outer Space Treaty, art. VIII.

¹⁸⁸ 763 F. Supp. 1327 (D. Md. 1991), *aff’d in part, rev’d in part*, 978 F.2d 140 (4th Cir. 1992), *aff’d in part, rev’d in part*, 991 F.2d 94 (4th Cir. 1993).

¹⁸⁹ *Ibid.*

¹⁹⁰ While not binding on other circuits, this holding would be persuasive and offer logical support for a claim in another circuit.

¹⁹¹ *Ibid.*

on parties when there is a contractual relationship. Maryland law “holds that a claim for negligent misrepresentation is improper when, as here, the only relationship between the parties is contractual, both parties are equally sophisticated, and the contract does not create an express duty of due care in making representations.”¹⁹² In short, contractual duties may take precedence over common-law tort claims in future disputes between space-faring companies. This concept is particularly relevant to intentional conjunctions between U.S. private space companies that are bound by contract. Courts may look to the contract first when deciding what duty of care or responsibility a private party had in dealing with its contractual partner, possibly limiting tort-based claims.

The Fourth Circuit also held that the CSLA did not preempt INTELSAT’s gross negligence claim.¹⁹³ This holding means that Maryland’s common law tort claim for gross negligence is superior to an express federal law requiring cross-waivers for property damage, personal injury, and death for launch services. Under Maryland law, a waiver of the right to sue is ineffective in the case of gross negligence.¹⁹⁴ This holding shows a limit on contract law. The court was willing to give sophisticated parties deference as it pertained to contractual duties but was not willing to allow parties to waive liability for gross negligence.¹⁹⁵ In furtherance of this idea, Congress discussed the idea of gross negligence during committee discussions while drafting the 2004 Commercial Space Launch Amendments. During this discussion, Representative Bart Gordon stated, “I believe that we want to make sure that we do nothing in the legislation that would prevent redress against gross negligence when warranted.”¹⁹⁶ This was later codified in FAA regulations.¹⁹⁷ But a case-specific standard for gross negligence was never adjudicated during *Martin Marietta*, so that remains a significant legal question.

Procedural Issues, Insights, and Gaps

The *Martin Marietta* case and subsequent federal agency regulations and guidance documents have established that willful misconduct, deliberate damage, and gross negligence cannot be waived.¹⁹⁸ A possible issue is the lack of definition for any of these terms in the regulations or guidance documents. This is the same issue with the *Martin Marietta* holding, which failed to articulate a case-specific standard for “gross negligence.” One interpretation is that whichever federal court hears such a case would apply the standard of that state’s law. Which state’s law the federal court would use would be dictated by the contract, as in *Martin Marietta*, or by the state in which the federal court sits (i.e., a district court in California would use California state law). There is, however, another wrinkle to the analysis.

¹⁹² *Ibid.*

¹⁹³ *Ibid.* at 99.

¹⁹⁴ *Ibid.* at 100.

¹⁹⁵ Defined as “wanton or reckless disregard.” *Ibid.*

¹⁹⁶ H.R. Rep. No. 108-429, at 37 (2004).

¹⁹⁷ 14 C.F.R. § 440.17(b) (stating “Any waiver, release, assumption of responsibility or agreement to hold harmless and indemnify pursuant to this section does not apply to claims for bodily injury or property damage resulting from *willful misconduct* of any of the parties to the reciprocal waiver of claims.”).

¹⁹⁸ In addition to federal regulations, the FAA released a guidance document stating a waiver of claims “does not cover deliberate damage or gross negligence.” Federal Aviation Administration, *Reciprocal Waiver of Claims Requirements*, Advisory Circular No. 440.17-1, at 4 (Sept. 13, 2024).

In the 2015 Commercial Space Launch Competitiveness Act, Congress stated that federal courts will have exclusive jurisdiction over “any claim by a third party or space flight participant for death, bodily injury, or property damage or loss resulting from an activity carried out under the license . . .”¹⁹⁹ This adds a wrinkle because it applies specifically to third parties or space flight participants.²⁰⁰ It does not, expressly, apply to parties in a contractual relationship. Practically, this means two things. First, parties in a contractual relationship can bring a tort claim against the other party in either state or federal court, assuming both companies are American. Second, federal courts have the exclusive jurisdiction to hear cases from third parties, directly implicating the nonintentional conjunction scenario.

Another wrinkle is that the law applies to commercial space launch *license* holders and their license-based activities. This does not apply expressly to on-orbit actions because the 2015 Act does not mention on-orbit actions, and separately, because there is no requirement in any federal regulation for on-orbit operations to be licensed.²⁰¹ Therefore, there is no statutory hook that directly regulates on-orbit activities. And, even if an application encompasses on-orbit activities, it is unclear if the license holder’s actions on-orbit are justiciable pursuant to federal regulations, as there is no law granting any federal agency explicit purview over on-orbit activities. These questions have yet to be adjudicated and could have far-reaching consequences on how and where tortious action on-orbit is adjudicated.

Tort Law for On-Orbit Operations: Practical Applications and Evidentiary Gaps

While tort law and contract law have been used to adjudicate issues arising from space operations, those issues have usually dealt with the launch phase, where the statutory law is more developed. The crux of this report, however, asks: what would happen if and when spacecraft intentionally or unintentionally collide in orbit? As illustrated by the *Martin Marietta* case, tort law and contract law are suitable vehicles for parties to recover for losses. There are, however, several issues that need to be addressed for the process to be more effective. First, what standard of care do we impose on spacecraft operators, and how will we know when they have breached that standard of care? Second, assuming we can find a workable standard of care, applying tort law requires attributing fault. Attributing fault requires a fact-intensive inquiry from evidence that is difficult, if not impossible, to find on spacecraft in orbit. Finally, how does the increased use of AI and autonomy affect gathering evidence, assigning liability, and determining when a duty and subsequent standard of care were breached? To illustrate these gaps, this section will work through a hypothetical unintentional collision between spacecraft in orbit. This section will only cover an unintentional collision. An intentional collision, much like the issue in *Martin Marietta*, will most likely be governed by a pre-existing contract (e.g., a servicing contract between two space companies that will contain contractual dispute resolution language).

¹⁹⁹ U.S. Commercial Space Launch Competitiveness Act, Pub. L. No. 114-90, 129 Stat. 704 (2015) (codified as amended at 51 U.S.C. §§ 50901–50923 (2018)).

²⁰⁰ 51 U.S.C. § 50902 (20) (defining “space flight participant” as “an individual, who is not crew or government astronaut, carried within a launch vehicle or reentry vehicle.”).

²⁰¹ There are FCC regulations governing satellite communications operations, but those regulations do not include an exclusive grant of federal jurisdiction. *See* 47 U.S.C. § 301; 47 C.F.R. pt. 25 (to be replaced by 47 C.F.R. pt. 100 upon the effective date of the FCC 2026 Order).

The standard of care used on orbit is nebulous and untested. As previously noted, the Liability Convention states a fault-based liability, or negligence, scheme for damage caused in outer space.²⁰² While this does not apply to purely domestic issues, nor does it articulate a standard of care, it is a start with which to begin the analysis. That analysis begins with duty. For a tort cause of action to be successful in American courts, the plaintiff must show that the defendant owed him a duty, against which there is a minimum standard of care. In general, humans acting in the world owe a duty to the reasonably foreseeable plaintiffs that could be harmed by their actions.²⁰³ Accordingly, on-orbit spacecraft operators would owe other on-orbit spacecraft operators a duty to refrain from harmful conduct, even when not in a contractual relationship with one another. For instance, the owner of Satellite A owes the owner of Satellite B a duty to operate within the standard of care of a reasonably prudent person in similar circumstances; in this case, a reasonably prudent satellite operator. Put another way, “negligence is the conduct unintentionally falling below a standard of care imposed on all members of the community.”²⁰⁴ The question still remains: what is the standard of care for on-orbit operators?

One method that crosscuts the legal formalization is using industry standards and company best practices to illustrate community standards. In its January 30, 2026, FCC application, SpaceX stated that its constellation will use an “advanced, automated collision avoidance system for low-latency risk assessment and response” and “strongly urges all operators to follow these procedures”²⁰⁵ This document is one example of how individual industry actors are setting the community standards apart from statutes, agency rules, and other organizational guidelines. A court could, in theory, use the standards that SpaceX has established to create a usable standard of care benchmark for the industry. While not decisive, wide adoption by many market participants would bolster the use of these standards in a future tort case. How wide that adoption must be and to how many market participants would be issues for the court to decide. Regardless, future American courts will have to figure out how to create this new standard of care as on-orbit collisions make their way through litigation.

Even assuming there is a workable standard of care for courts to use, there are several evidentiary issues when adjudicating a tort claim on orbit. Attributing fault is a fact-intensive inquiry. The Second Restatement of Torts states that the plaintiff has the burden of proof of showing facts that give rise to a legal duty and subsequent standard of conduct, facts that show the defendant failed to conform to that standard of conduct, facts that show the failure was a legal cause of the plaintiff’s harm, and facts that show the plaintiff in fact suffered harm that is legally compensable.²⁰⁶ All of that to say, the plaintiff needs a lot of facts to recover in a tort claim. Finding these facts could be extremely difficult, if not impossible, in the context of on-orbit operations. First is the issue of attribution. As stated, there are thousands upon

²⁰² Liability Convention.

²⁰³ See *Palsgraf v. Long Island Railroad Co.*, 248 N.Y. 339, 350 (1928) (stating “Every one owes to the world at large the duty of refraining from those acts that may unreasonably threaten the safety of others.”).

²⁰⁴ Stefan-Michael Wedenig, “The Liability of States for Narrow AI in Space Applications: Some Preliminary Considerations,” *German Journal of Air and Space Law* 73, no. 2 (2024).

²⁰⁵ Application of Space Exploration Holdings, LLC for Authority to Launch and Operate the SpaceX Orbital Data Center System, ICFS File No. SAT-LOA-20260108-00016, at 4 (F.C.C. Jan. 30, 2026).

²⁰⁶ American Law Institute, *Restatement (Second) of Torts* § 328A (1965).

thousands of unattributable pieces of space debris in orbit at any given time. If one of these pieces of debris were to cause substantial damage to an orbiting data center, and the owner of that data center wanted to bring a tort claim to recover compensation for the damage, from whom would the owner recover?

Without a defendant, there can be no tort claim. In this type of collision, tort law would not be a path forward. But say, for example, the owner knows that his satellite unintentionally collided with another satellite. How can that owner show negligence? While many satellites have automatic collision avoidance systems, such systems are not universal. Is that enough to show negligence? What if the other satellite had an experienced operator at the helm while the owner's satellite was controlled almost exclusively by AI? Does that change the negligence analysis? Even if there are two humans in the loop, how do you get the play-by-play of what happened just prior to the collision? For a terrestrial negligence claim involving a motor vehicle accident, the court will hear from several witnesses, look at contemporaneous video camera footage, and interview the parties themselves. But in outer space, the availability of sensors that could be used to adjudicate such a claim is far more restricted. Likewise, any navigation data and command and control sequences from the satellites themselves could be protected as proprietary information, making it hard for it to enter court as relevant evidence. These evidentiary restrictions make attributing fault for an on-orbit collision extremely difficult for subject matter experts, let alone courts of general subject matter knowledge, such as state and federal courts. These evidentiary concerns are multiplied by the increasing use of AI and autonomy in on-orbit maneuvers.

Autonomous spacecraft augmented with AI bring the liability issues from Earth into orbit. One of the biggest issues for tort claims involving AI-augmented systems is the liability analysis. This issue is already in play on Earth in the context of self-driving cars in the case of automation. Some scholars have argued that “[a]utonomous vehicles will shift the responsibility for avoiding accidents from the driver to the vehicle manufacturer”²⁰⁷ and could implicate several entities including the vehicle manufacturer, the software engineer who programmed the code for the autonomous operation, and the component manufacturer of the autonomous system.²⁰⁸

This idea has played out in court in the *Nilsson* case, where the complaint against a self-driving Chevrolet Bolt alleged General Motors breached its duty of reasonable care to other motorists when its autonomous system failed to execute the proper lane-change maneuver and injured another motorist.²⁰⁹ Notably, General Motors admitted that its system was required to use reasonable care in driving.²¹⁰ While the case ultimately settled, it is influential as it is one of the first instances, in court, that a manufacturer of an autonomous navigation system admitted that its autonomous product had a duty to follow a standard of care usually reserved for humans. This

²⁰⁷ Gary E. Marchant and Rachel A. Lindor, “The Coming Collision Between Autonomous Vehicles and the Liability System,” *Santa Clara Law Review* 52 (2012): 1321, 1339.

²⁰⁸ *Ibid.* at 1328.

²⁰⁹ *Nilsson v. General Motors LLC*, No. 4:18-cv-00471-KAW, Complaint for Damages, ECF No. 1 (N.D. Cal. Jan. 22, 2018).

²¹⁰ *Nilsson v. General Motors LLC*, No. 4:18-cv-00471-JSW, Answer and Demand for Jury Trial, ECF No. 18 (N.D. Cal. Mar. 30, 2018).

assertion has far-reaching implications for liability in space, as it opens the door for a negligence claim based on a breach of duty by an autonomous system.

While there is no explicit mention of AI in the *Nilsson* case, cases alleging negligence on the part of AI companies for harms caused to plaintiffs have reached American courts. Many of these cases, however, have settled. In *Garcia v. Character Technologies, Inc.*, the plaintiff alleged, among other things, defective product design and negligence in exercising reasonable care toward minors against a maker of an AI character application.²¹¹ As with the *Nilsson* case, *Garcia* also settled.²¹² But these two cases together have several implications for resolving disputes involving AI and autonomous systems in outer space. First, the idea that an autonomous or AI entity can act negligently on behalf of the principal is no longer novel. Courts are starting to see these cases and causes of action. While they have not adjudicated on the finer points of standards of care, courts and corporations seem to have accepted that a negligence claim against a company resulting from its use of AI and autonomous systems is justiciable. Second, how this will translate to space operations is unclear, as even human-based tort claims have yet to be adjudicated. However, courts will be able to use the terrestrial examples of self-driving cars as an analog in adjudicating such a claim.

One notable exception is the recent Tesla verdict. In August 2025, a federal jury in *Benavides v. Tesla, Inc.* found Tesla 33% liable in a wrongful death action involving its Autopilot system, and the trial court denied Tesla's post-trial motions in February 2026.²¹³ Unlike *Nilsson* and *Garcia*, which established only that duty and design-defect theories *could* be pled against autonomous-system makers before settling, *Benavides* fused both theories and produced a contested liability finding. The jury found for the plaintiff on design defect, failure to warn, negligence, and gross negligence pursuant to Florida law. The jury relied in part on Tesla's own marketing representations to define the standard of care, and the verdict supplies the worked gross-negligence application that *Martin Marietta* declined to resolve. Of note, Tesla was found grossly negligent as it pertained to its knowledge of a defect in the Autopilot's driver monitoring system.²¹⁴ This finding could translate to an on-orbit context. For example, suppose a SpaceX satellite's automated collision avoidance system failed to execute a maneuver during a high-probability conjunction and struck a competitor's spacecraft. The operator of the damaged satellite could—on the *Benavides* model—plead negligence and design defect against SpaceX, using SpaceX's January 30, 2026, FCC representations about its “advanced, automated collision avoidance system” to attempt to define the standard of care that SpaceX failed to meet. The analogy is imperfect: the *Benavides* plaintiffs were pedestrians outside any commercial relationship with Tesla, whereas competing on-orbit operators may share contractual or regulatory obligations that complicate the duty analysis under *Martin Marietta*'s reasoning.

²¹¹ Complaint for Wrongful Death and Survivorship, Negligence, Filial Loss of Consortium, Violations of Florida's Deceptive and Unfair Trade Practices Act, and Injunctive Relief, *Garcia v. Character Technologies, Inc.*, No. 6:24-cv-01903-ACC-EJK (M.D. Fla. Oct. 22, 2024), ECF No. 1.

²¹² Order of Dismissal, *Garcia v. Character Technologies, Inc.*, No. 6:24-cv-01903-ACC-DCI (M.D. Fla. Jan. 7, 2026), ECF No. 244.

²¹³ *Benavides v. Tesla, Inc.*, No. 1:21-cv-21940-BLOOM/Torres (S.D. Fla. Feb. 19, 2026) (denying defendant's renewed motion for judgment as a matter of law and alternative motion for a new trial); jury verdict, Aug. 1, 2025 (around \$42.6 million in compensatory and \$200 million in punitive damages).

²¹⁴ *Ibid.*

Likewise, a potential plaintiff would most likely look at marketing-oriented representations, not necessarily representations made pursuant to a federal agency filing, in order to win a products liability case. While not a perfect analog, the *Benavides* case shows how there are several avenues within tort law itself upon which liability for on-orbit operations could be adjudicated.

In sum, the future of tort and contract disputes for on-orbit activities is unknown, but there are guideposts along the way that policymakers and courts can use to help create a dispute resolution system that does not unnecessarily stifle innovation but still provides compensation to companies for their capital expenditures on orbit.