



NATIONAL ORBITAL DEBRIS IMPLEMENTATION PLAN

Product of the
ORBITAL DEBRIS INTERAGENCY WORKING GROUP
SUBCOMMITTEE ON SPACE WEATHER, SECURITY, AND HAZARDS

of the
NATIONAL SCIENCE AND TECHNOLOGY COUNCIL

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About the Orbital Debris Interagency Working Group

The Orbital Debris Interagency Working Group, organized under the auspices of OSTP, coordinates science and technology policy, strategy, and federal research and development (R&D) pertaining to orbital debris hazards. This coordinated effort aims to ensure U.S. leadership in addressing the challenge orbital debris poses to the safety and sustainability of space.

About this Document

This document provides an interagency implementation plan to guide the actions of the U.S. Government (USG) in addressing orbital debris challenges. This Orbital Debris Implementation Plan directly supports the United States Space Priorities Framework, with a focus on addressing the safety and sustainability of the space environment due to intended and unintended orbital debris events. This document supports and is consistent with National Space Council-led interagency work implementing Space Policy Directive-3.

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Executive Summary

The United States' leadership in space activities, from exploration to developing new technologies, offers new opportunities across multiple sectors as well as new possibilities to improve life on Earth. Earth's orbits, however, are finite resources and can be threatened by the rapid, uncontrolled increase in orbital debris. The challenges posed by orbital debris to the sustainability of outer space have inherent similarities to other human-made global environmental challenges. The consequences of not mitigating, tracking, or remediating orbital debris could render certain orbital regimes unsafe or unusable for satellites to operate. Thus, U.S. leadership in space entails a responsibility to promote a safe and sustainable space environment for future generations.

This Orbital Debris Implementation Plan provides tangible actions the United States will pursue to address the hazards posed by orbital debris. The Interagency Working Group (IWG) developed this plan to ensure activities related to space debris, such as monitoring the orbital debris environment, understanding the effects of space weather on satellite predictions, regulating space activities, remediating debris, and working with the international community, are coordinated efforts across U.S. Government departments and agencies.

This Implementation Plan accomplishes objectives outlined in the U.S. Space Priorities Framework.¹ This Implementation Plan also builds upon the National Orbital Debris Research and Development (R&D) Plan published in 2021.² The 2021 R&D Plan described a framework to understand orbital debris challenges and identified several R&D topic areas that could be pursued to address debris risks. The actions included in this document leverage input collected from the space community through public engagements, such as a Request for Comment,³ listening sessions, and workshops. The plan identifies 44 specific actions for agencies to lead across three pillars:

1. Debris Mitigation

Debris mitigation is defined as designing to prevent or limit the creation of new debris. It encompasses measures taken before an individual object becomes classified as debris. It includes any hardware or software configurations that would be implemented into the design of launch vehicles, satellites, or space missions and mission profiles that have the intention or outcome of minimizing the generation of debris in orbit. Add-on devices for trackability and on-board propulsion for spacecraft maneuverability, insofar as those technologies help prevent the creation of new debris, are also considered under this pillar.

2. Tracking and Characterization of Debris

Tracking and characterizing debris describes any technology, methodology, or modeling that involves the detection, tracking, or characterization of debris or the debris population. It includes

¹ U.S. Space Priorities Framework. December 2021. <https://www.whitehouse.gov/wp-content/uploads/2021/12/United-States-Space-Priorities-Framework--December-1-2021.pdf>.

² National Orbital Debris Research and Development Plan. National Science and Technology Council. January 2021. <https://trumpwhitehouse.archives.gov/wp-content/uploads/2021/01/National-Orbital-Debris-RD-Plan-2021.pdf>.

³ Office of Science and Technology Policy. Orbital Debris Research and Development Plan. Notice of Request for Comment at 86 FR 61335. November 2021.

the modeling of debris to predict where space objects will be located in the future. In addition to modeling debris population, the same technologies and methodologies may be applied to detecting, tracking, and characterizing active satellites.

3. Remediation of Debris

Remediation of debris refers to technologies and methods for maintaining or reducing the current debris population by active means. This definition includes Active Debris Removal (ADR) technologies, neutralizing or revival strategies, just-in-time collision-avoidance methods, and technologies related to on-orbit servicing, and rendezvous and proximity operations including the operation of grappling mechanisms, object manipulators, and capture devices. Recycling and repurposing of debris are considered in this pillar and enabled through research activities for remediation.

The Implementation Plan informs the policy development process. Specific actions identified in the Plan may evolve in response to advances in technology and other factors and will be refined over time. Any commitment of federal resources to support the activities outlined in this document will be determined through the regular budget process and subject to the availability of appropriated funds.

This National Orbital Debris Implementation Plan is consistent with, and meets some objectives outlined in Space Policy Directive-3 (SPD-3), the National Space Traffic Management Policy. The Orbital Debris Interagency Working Group (IWG) is focused on orbital debris rather than space situational awareness; however, the overlap between the two issues is notable, particularly as it pertains to the tracking and characterization of orbital debris. The National Space Council (NSpC) and the Office of Science and Technology Policy (OSTP) are coordinating on these two parallel efforts.

Introduction

Orbital debris, sometimes referred to as “space junk,” is defined as human-made, non-functional objects—including fragments and elements thereof—that exist in Earth orbits or are re-entering Earth’s atmosphere.⁴ This definition is consistent with SPD-3, issued in May 2018, which stated “Orbital debris, or space debris, shall mean any human-made space object orbiting Earth that no longer serves any useful purpose.”⁵

Orbital debris, like all objects in Earth orbit, travels at tremendous speeds—averaging about 10 kilometers per second in Low Earth Orbit (LEO). By its nature, the movement of orbital debris is uncontrolled, and its orbital parameters can be difficult to predict. Due to the combination of their considerable speed and uncontrolled movements, pieces of orbital debris can endanger operational spacecraft through risk of collision. Because new satellites are being launched at a fast pace, the space community has become more concerned about potential conjunctions and debris causing events. The proliferation of space debris creates uncertainty and risk for all actors in the orbital environment, not only satellite operators, but also for those seeking to invest in or expand their business model with space-based capabilities.

Numerous U.S. Government departments and agencies are involved in orbital debris risk management. The National Aeronautics and Space Administration (NASA) uses radars, telescopes, and in situ measurements to statistically sample debris too small to be tracked but still large enough to threaten human spaceflight and robotic missions. NASA also leads the development of the U.S. Government Orbital Debris Mitigation Standard Practices (ODMSP), which are directly applicable to U.S. Government operators.⁶ NASA also maintains an office to monitor the space environment for its own satellites. The Department of Defense (DOD) collects data on and tracks space objects and notifies spacecraft operators of possible collision. DOD is transitioning the responsibility of providing notifications for civil and commercial operators to the Department of Commerce (DOC). The Federal Aviation Administration (FAA) and the Federal Communications Commission (FCC) have policies or regulations that are intended to limit the creation or accumulation of debris.

As a result of the deliberations of the IWG and considering input from the stakeholder community, OSTP has developed a comprehensive Orbital Debris Implementation Plan to address the orbital debris challenges faced by the United States and other spacefaring nations. This plan is organized into the three pillars: 1) Debris Mitigation, 2) Tracking and Characterization of Debris, and 3) Remediation of Debris.

⁴ Inter-Agency Space Debris Coordination Committee (IADC). 2007. “IADC Space Debris Mitigation Guidelines.” IADC-02-01, Revision 1, September 2007. <https://www.unoosa.org/documents/pdf/spacelaw/sd/IADC-2002-01-IADC-Space-Debris-Guidelines-Revision1.pdf>.

⁵ Space Policy Directive – 3 (SPD-3), National Space Traffic Management Policy, 83 FR 28969 (June 18, 2018).

⁶ U.S. Government Orbital Debris Mitigation Standard Practices, available at https://orbitaldebris.jsc.nasa.gov/library/usg_orbital_debris_mitigation_standard_practices_november_2019.pdf.

Implementation Actions

1. Debris Mitigation

Improve Component Design to Mitigate Debris Creation

- 1.1. Explore the use of grand challenges or prizes to address debris generation and to improve designs to mitigate debris on orbit.
 - 1.1.1. Explore the use of grand challenges or prizes to address debris generation. Among the proposed solutions offered for limiting/preventing debris generation and mitigating debris on orbit, assess their suitability for crowdsourced solutions. Recommend the most suitable for grand challenges and prizes. (Lead: DOD and NASA)
- 1.2. Conduct research and develop options aimed to refine payload separation and deployment to minimize or eliminate debris generation.
 - 1.2.1. Conduct research to improve understanding on where and how debris is being generated during launch staging and payload deployment, and, from that, develop innovative solutions to limit or prevent debris creation. (Lead: FAA; Support: NASA, DOD)
 - 1.2.2. Conduct R&D on minimizing the probability of accidental explosion of operational and defunct batteries, propulsion systems, and other subsystems/components with histories of explosions. (Lead: NASA; Support: DOC)
- 1.3. Conduct a survey of currently utilized technical actions for limiting debris by design.
 - 1.3.1. Survey companies for actions they are currently taking to operate within the parameters of debris creation listed in the United States Government (USG) Orbital Debris Mitigation Standard Practices (ODMSP). A survey can help identify solutions and actions companies are taking to limit debris creation during launching and normal operating modes. From this, the USG can develop and maintain a compendium of best practices for design, build, and testing of critical components of upper stages and spacecraft. (Lead: DOC and NASA)
- 1.4. Conduct research on maneuver options.
 - 1.4.1. Conduct research on and develop software to generate feasible close approach mitigation and maneuver instructions consistent with the physics-based and operational constraints of spacecraft and operators—and do so autonomously. (Lead: NASA and DOD; Support: DOC)

Best Practices, Guidelines and Websites

- 1.5. Educate the space operator community on best practices for mitigating debris creation.
 - 1.5.1. Develop and maintain a website, with guidance from the space operator (commercial), government, and international communities, to educate and discuss best practices as a resource for the new space operator community that may be unaware of developments and advances in debris mitigation design choices. (Lead: DOC; Support: NASA, DOD, FAA, DOS)

1.6. Develop a safety framework for owner/operator data sharing on anomalies for safety purposes—akin to the safety reporting system developed for Air Traffic Management.

1.6.1. Explore developing a database for satellite operators to report on anomalies and, if available, the root causes of the anomalies and lessons learned. Investigate concepts for timely shared knowledge among spacecraft owners/operators that will propagate best practices on a useful timescale. DOD would lead in the short-term, transitioning to DOC when information can be incorporated into the software architecture or repository. (Lead: DOD until transition to DOC; Support: NASA, DOC)

1.7. Revisit deorbit guidelines.

1.7.1. Reevaluate ODMSP, including deorbit guidelines, by prioritizing a short-term study to better understand the impact of changing deorbit requirements for the USG, specifically the potential benefits and cost in reducing the deorbit timelines. (Lead: NASA; Support: DOC, DOD, FAA, FCC)

Refine Techniques for Conjunction Risk Assessment and Collision Avoidance

1.8. Prioritize safe on-orbit operations.

1.8.1. Use shared rules on orbit including deconfliction, on-orbit safety, right-of-way to enhance efficiency and safety of spaceflight operations to create a website of conjunction assessment educational materials and best practices. (Lead: DOC; Support: NASA, DOD, DOS)

1.8.2. Establish periodic and coordinated whole-of-government review of licenses for new satellites before development to incorporate safe practices into operations concept and demonstrate adequacy of planned conjunction assessment process. (Lead: FAA; Support: NASA, DOD, DOC, FCC, DOS)

Improve Shielding, Impact Resistance, and Overall Resilience of Spacecraft Surfaces

1.9. Develop capabilities to detect, attribute, and characterize orbital debris strikes and effects upon spacecraft on orbit.

1.9.1. Conduct a cost-benefit analysis to understand value of incorporating new technologies onto spacecraft systems to detect and characterize orbital debris strikes. Based on outcome of analysis, promote R&D for improved capabilities to detect such strikes on-orbit. (Lead: NASA)

1.10. Further develop solutions to address orbital debris impact resistance.

1.10.1. Prioritize research to improve hypervelocity impact capabilities and develop new protection techniques and new shielding methodologies, such as developing new multifunctional shields using nanostructures or self-healing materials. (Lead: NASA)

1.10.2. Determine the failure criteria for pressure vessels based on hypervelocity impact tests and analyses. The failure criteria may include determination of ballistic limits for common shield materials and configurations to meet impact protection requirements and accurately quantify spacecraft risk. (Lead: NASA)

- 1.10.3. Develop ballistic and penetration equations relating spacecraft vulnerability to debris size, mass, material density, shape, velocity speed, and impact angle based on hypervelocity impact simulations testing supported by modeling and simulations tests. (Lead: NASA)

Design Add-on Devices for Improved Tracking, Maneuvering, and Remediation

- 1.11. Research incorporating add-on remediation or removal.
 - 1.11.1. Conduct research and trade studies on incorporating new technologies such as drag enhancement devices and automated disposal systems. Studies may include challenges and barriers to incorporating hooks or devices designed into the system and used for active debris removal. Consider limiting reentry human casualty risk when developing disposal/removal technologies. (Lead: NASA; Support: DOC)
 - 1.11.2. Conduct R&D for affordable, available sensor technologies, such as light-weight beacon devices, GPS or ephemerides sharing transponders, and ultra-lightweight radar reflectors, for micro/CubeSats to reduce tracking errors and increase accuracy of collision prediction. (Lead: NASA; Support: DOC)

2. Tracking and Characterization of Debris

Space Environment Prediction

- 2.1. Improve current empirical atmospheric density models.
 - 2.1.1. Prioritize implementing a method of collecting and archiving GPS ephemerides and similar data collected by commercial entities that may improve empirical atmospheric density models. Determine how to use this information to estimate atmospheric drag for orbital predictions as part of the software architecture providing ground. (Lead: DOC; Support: DOD)
 - 2.1.2. Improve coordination and sharing between NOAA and NASA to address space weather effects on the modeling of the orbital debris environment. NOAA and NASA should continue partnering to advance R&D in support of space situational awareness and orbital debris, specifically addressing orbital debris tracking and characterization, research to operations development, and the impacts of dust and small orbital debris on satellites. (Lead: DOC; Support: NASA, DOD)

Object Characterization, Tracking and Custody

- 2.2. Identify potential improvements for conjunction assessments and collision avoidance.
 - 2.2.1. Expand the current catalog of resident space objects to include parameters of the objects that are necessary for the design of debris remediation. Parameters may include size, mass, and geometry of object, tumbling characteristics, and potential hard-points or fiducials, which benefit removal, and post-mission decommissioning actions. (Lead: DOD until transition to DOC; Support: DOC, NASA)
 - 2.2.2. Sponsor R&D for determining material properties, shape, and orientation of existing debris objects. Steps may include leveraging existing facilities and radiation chambers to

- study material properties and structure when exposed to different radiation levels observed at different altitudes. For example, using R&D to understand how collimated light interacts with a satellite at all different orientations. (Lead: DOD; Support: NASA)
- 2.2.3. Sponsor academic light curve research, which has the potential to observe changes in material properties and structure in trackable debris. Assess benefits of upgrading optical telescopes for researchers to collect multispectral and hyper-temporal imaging data that captures transient effects, i.e., glints, that happens on short timescales as the objects are rotating and tumbling. Conduct further studies to research automated processing of photometry data, taking advantage of existing developments for large astronomical surveys. (Lead: DOD; Support: NASA)
- 2.2.4. Research ways to improve the accuracy of sensor tracking measurements; expand satellite tracking orbital coverage, particularly in the Southern Hemisphere; and examine the cost-effectiveness and implications to policy and astronomical observations of requiring new satellites to include tracking aids, such as laser corner reflectors and dipoles. (Lead: DOD; Support: NASA)
- 2.2.5. Sponsor a study to determine which objects in the DOD satellite catalog would substantially benefit from additional data sources and identify how best to acquire said data. The study should also determine how to validate non-Space Surveillance Network (SSN) data, and how to validate purchased commercial data to make it available for the catalog maintenance. (Lead: DOD; Support: DOC)
- 2.2.6. Perform an analysis to identify radar tracking and catalog custody limits. Analyze radar frequencies of tracking, characterizing, and maintaining custody of objects 1-10 cm in order to identify the necessary types of sensors or other characterizing techniques. Identify the number and types of radars needed to characterize the distributed scales of debris clouds. (Lead: DOD; Support: NASA)
- 2.2.7. Pursue R&D opportunities to understand the interaction of orbital debris with the surrounding space environment, and whether the resulting phenomena can be used for the detection, mapping, and tracking of currently nontrackable (< 10 cm) orbital space debris. Pertinent physical phenomena may include plasma density solitary waves (solitons), electrostatic discharge, orbital decay, magnetic field perturbations, and/or radio wave emissions produced as the orbital debris interacts with the surrounding plasma environment. (Lead: ODNI; Support: NASA)
- 2.3. Improve characterization of debris less than 1 cm in LEO.
- 2.3.1. Investigate technology development and mission opportunities for in-situ measurement sensors to identify, develop, and mature in-situ measurement technologies; leverage researched technologies; and encourage the development of novel concepts capable of collecting similar types of data, including size, mass, material density, speed, and direction, on the millimeter-sized orbital debris. Identify mission opportunities to deploy sensors to collect statistically meaningful data on the millimeter-sized orbital debris between 600 km and 1000 km altitudes. (Lead: NASA; Support: DOD)
- 2.3.2. Conduct research that links spectral changes due to pits in the satellite surface created by orbital debris, such that all maintained objects in all orbital regimes could be used as orbital debris sensors, allowing for debris populations across all orbits. In parallel,

- develop “aging characterization” models to characterize how satellite optical spectral reflections change over time due to the space environment. (Lead: ODNI)
- 2.3.3. Investigate the use of debris-attributable satellite movement data from commercial satellite operators. This data could be used to estimate the flux, mass, impact speed, and quantity of millimeter-sized debris objects in commonly used orbital regimes to provide improvements to bound predictions from orbital debris models and risk assessment. These movements would also be useful to orbital regimes, debris modeling, and risk assessment to further estimate the debris population. (Lead: DOC; Support: NASA).
- 2.4. Improve the efficiency of sensor tasking.
- 2.4.1. Prioritize research that analyzes how to acquire more satellite tracking data from existing systems. Object tracking accuracy is influenced by the amount, distribution, and quality of sensor measurements. Improving the output of existing sensors would expand the accuracy of the satellite catalog. (Lead: DOD)
- 2.5. Incorporate sources of debris production and reduction into orbital debris characterization models.
- 2.5.1. Identify options to develop an orbital debris environment model that dynamically accounts for debris increases and decreases. The model should account for yearly launch rates, satellite collisions, debris impacts, and anti-satellite tests as well as expected reduction of satellite losses per year due to proposed debris mitigation and remediation technologies. The model should also track the cost of implementing each mitigation and remediation technology to a quantifiable reduction in rate of satellite mission loss. (Lead: NASA; Support: DOD and DOC)

Conjunction Assessment

- 2.6. Identify potential improvements for conjunction assessments and collision avoidance.
- 2.6.1. Conduct research to improve collision avoidance. Examine decision thresholds for collision avoidance maneuvers; characterize confidence levels needed for execution; and determine appropriate mitigation levels for various scenarios. Based on the study examining decision thresholds, perform sensitivity analyses on factors that may affect orbital prediction accuracy in order to determine the ways in which orbital accuracy can be improved. The factors considered may include radar tracking accuracy, the number of tracks per day, solar pressure, and space weather’s effects on atmospheric drag. For each factor, determine the limit of orbit prediction accuracy improvement beyond which no operational improvement would be observed. (Lead: NASA and DOD; Support: DOC)

Research to Operations

- 2.7. Transition research on debris tracking and characterization into operational capabilities or protection for future space missions.
- 2.7.1. Balance representation on U.S. Government algorithm and model development advisory committees and working groups to encourage the introduction of new approaches and new ideas. Seek subject matter expertise from Space Force, Air Force Research Laboratory, Defense Advanced Research Projects Agency, Missile Defense Agency (DARPA), NASA, Federally Funded Research and Development Centers

- (FFRDCs), commercial industry, and academia. A collaboration between government and non-government would ensure there is a process for astrodynamics and computation specialists to participate in improving the algorithms used in space command and control applications and government software architectures. (Lead: DOD; Support: DOC, NASA)
- 2.7.2. Provide a research collaboration platform to the orbital debris community such as an open-architecture, application programming interface to facilitate the bidirectional exchange of data, algorithms, and documentation with academia, research centers, such as FFRDCs, and commercial entities. The platform would encourage non-USG interactions with the USG, and validate developed tools, algorithms, or models. (Lead: DOD; Support: DOC, NASA)
- 2.7.3. Review information distribution policies for the distribution of simplified General Perturbations 4 and propagated ephemerides, both of which enhanced insight into pending conjunctions and sensor tracking data. (Lead: DOD transitioning to DOC; Support: NASA, DOC)

3. Remediation of Debris

R&D Cost and Risk

- 3.1. Improve analyses of risks posed by orbital debris on operationally-relevant timescales
- 3.1.1. Develop a risk framework to include negative effects to stakeholders that rely on space-enabled services. Convene stakeholders to discuss how their operations may be affected by various orbital debris scenarios. Potential stakeholders may include entities that provide the following services: communications, civil protection, air quality monitoring, oil and gas production, agriculture, security, ocean monitoring, renewable energies, and forestry. (Lead: NASA; Support: DOC)
- 3.1.2. Perform an economic and strategic risk assessment. An economic and strategic risk assessment would describe the near-term harm—quantified in dollars and probabilities—to provide an expected value for costs imposed by orbital debris and, by extension, the potential size of the market for active debris removal (ADR) services. (Lead: NASA; Support: DOC, DOD)
- 3.2. Estimate costs to develop and perform debris remediation.
- 3.2.1. Estimate the costs of incorporating debris remediation technologies into satellites, identify and prioritize remediation options that could be incorporated into the design of spacecraft and upper stages—such as fiducials and contact points for docking, drag sails, and tethers—and estimate the cost of incorporating the technologies into the design and operation of small and large satellites. The costs of preparing client satellites for remediation will inform cost-benefit analyses of incorporating such options into spacecraft and upper stages. (Lead: NASA, DOC, and DOD)
- 3.2.2. Collaborate with industry to develop representative cost estimates for various remediation capabilities. The USG envisions that industry will play the leading role in providing remediation services. Through collaboration with industry stakeholders—which may include studies, requests for information, or other mechanisms—a set of cost

scenarios should be produced to inform priorities and funding for remediation R&D. (Lead: NASA and DOD; Support: DOC)

3.3. Develop and use common metrics to measure risk.

3.3.1. Develop a process to identify and prioritize the metrics for measuring risk to yield different potential approaches for mitigating and remediating the risk. With priority metrics chosen, efforts to remediate debris can be assessed and cost-benefit analyses can be updated to include the metrics, if needed. (Lead: NASA; Support: DOC, DOD)

R&D Debris Remediation Technologies

3.4. Use comprehensive trade studies for debris remediation to guide investments.

3.4.1. Create a trade study of remediation options for large (and small) debris to compare the efficacy and cost of all debris remediation modalities (e.g., move, remove, reuse) in all orbital regimes (LEO, MEO, GEO) to guide further technology development. The study should address remediation of acute debris events and long-term debris environment sustainability, and leverage the debris object catalog to assess the priority and difficulty of remediation associated with each debris object. Measures of merit may include near- and long-term benefit, cost, technical feasibility, effectiveness of debris removal, and mission effects. (Lead: NASA and DOD; Support: DOC)

3.5. Advance enabling technologies for remediation and repurposing.

3.5.1. Advance Technology Readiness Levels (TRL) of high-efficiency and refuellable propulsion systems that could enable multiple object removal per launch and satellite servicing capabilities. (Lead: DOD and NASA; Support: FAA)

3.5.2. Support development and validation of end-of-mission capture and relocation interface standard for space objects. If routinely implemented on satellites, upper stages, and deployment devices, such a standard may encourage the creation of a market for ADR services. A standard interface may increase the confidence of government operators and regulators that ADR services can be used to satisfy Post-Mission Disposal (PMD) requirements. (Lead: DOD; Support: DOC, NASA)

Policy, Regulation, and Cooperation

3.6. Develop a process to determine whether ADR services can satisfy PMD requirements.

3.6.1. Develop a process by which the interagency can determine whether and how ADR services can satisfy PMD requirements. This action is related to an aforementioned action about validating and adopting interface standards. (Lead: DOD; Support: FCC, NASA, DOC)

3.7. Advance consideration of international issues related to remediation of orbital debris.

3.7.1. Assess legal and other issues related to remediation of orbital debris, including ownership, return, and other significant issues that may arise in relation to the Outer Space Treaty and the other core space treaties. While such situations may need to be resolved on a case-by-case basis, clarity of the U.S. approach with respect to such issues where possible and appropriate may encourage the development of remediation options. (Lead: DOS; Support: DOC, DOD, FAA, FCC, NASA)