AMERICAN FOREIGN POLICY COUNCIL

Space Policy Initiative

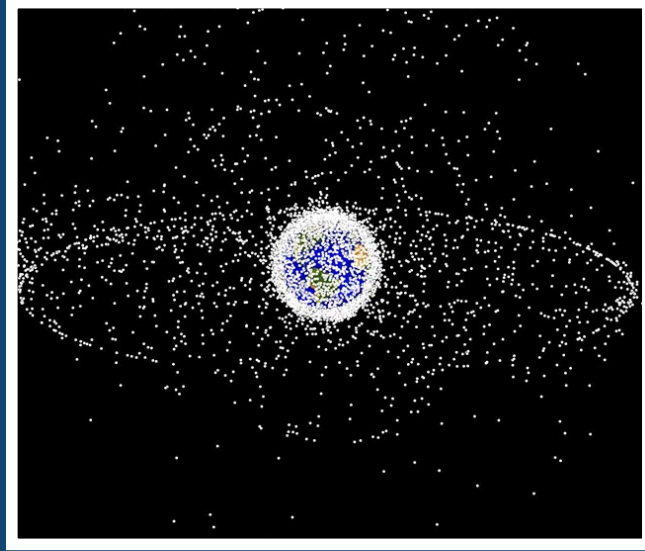
Space Policy Review

The Imperative for United States Engagement in a Global Space Debris Cleanup Program

By: Dr. Tom Cooley

The Big Picture

- Proliferation of space debris is a result of decades of space exploration, technological advancements, expanding governmental and commercial activity in space, and multiple destructive anti-satellite tests.
- Development of advanced technologies for debris removal, tracking, and collision avoidance is essential. As space debris varies in size, shape, and orbital characteristics, designing effective and versatile cleanup systems is a challenge.
- A comprehensive space debris cleanup program requres financial investments, research and development efforts, and international cooperation.
- Numerous U.S. allies have established orbital debris programs. America is behind and needs to initiate a significant program to pursue this noble aim.
- By investing in debris cleanup, nations can ensure the security and sustainability of space activities, promoting the long-term benefits of space exploration and utilization. Legislation is necessary to provide adequate funding for debris removal.



Source: NASA

As the world becomes increasingly reliant on space-based technologies, the proliferation of space debris poses a significant threat to our shared orbital environment.The United States should proactively engage with other nations and initiate a comprehensive program to clean up the space debris problem. Space economic opportunities abound, but the promise of this important commercial domain is hindered by the growing space debris problem. The challenges posed by space debris, the importance of international cooperation, potential benefits, and a framework for a collaborative approach to address this pressing issue are expanded upon in this paper. By taking a leadership role in space debris cleanup, the United States can safeguard its space

Dr. Tom Cooley *is the President of TC Space Consulting, where he advises large and small space companies on a range of topics. Previously he spent over 25 years working for the U.S. Air Force Research Laboratory (AFRL). In his senior most position there, Dr. Cooley served as the Chief Scientist, Space Vehicles Directorate, where he was responsible for the technical quality of a $200 million-per-year Air Force space science-and-technology investment, coordinating the space investments across the DoD. He has published over 70 papers in national and international journals or conferences.*

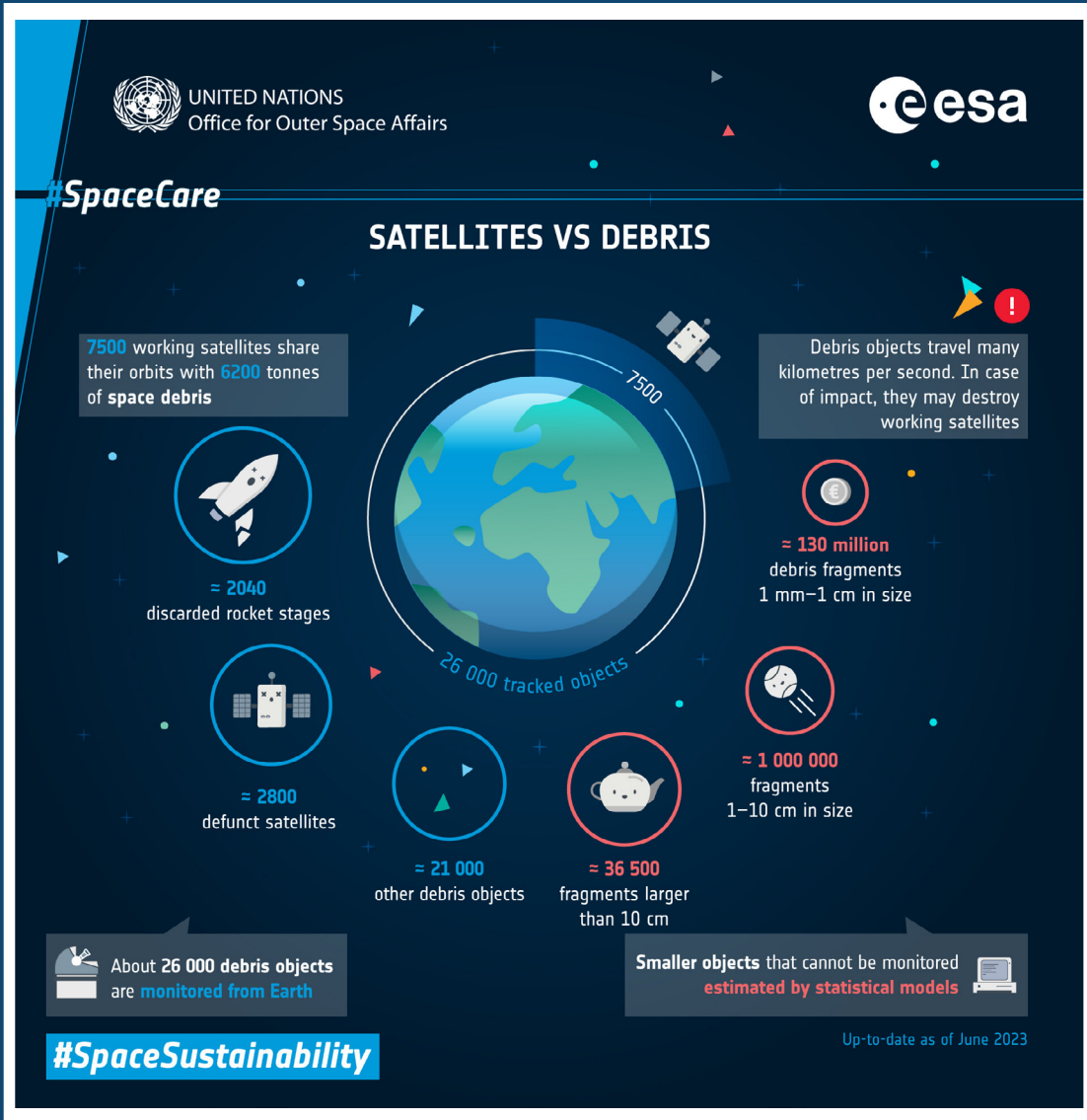
assets, promote peaceful space activities, and foster global cooperation in the realms of science, technology, and security.

Space debris—consisting of defunct satellites, spent rocket stages, and fragments resulting from collisions—poses an ever-increasing threat to space activities. The exponential growth of space debris jeopardizes the sustainability of space endeavors, raises the potential for catastrophic collisions, and hinders the exploration and utilization of outer space. There is now a compelling case for the United States to lead a collaborative international effort to set standards, implement commercial rules, and initiate a campaign to clean up U.S.-origin space debris, thus demonstrating U.S. leadership with a proactive approach to tackling this global challenge. The United States has done well to promote standards, but much more action is needed.

The Growing Threat of Space Debris

The proliferation of space debris is a result of decades of space exploration, technological advancements, expanding governmental and commercial activity in space, and multiple destructive anti-satellite tests by nation-states (including the United States).[1] The crowded low-Earth-orbit region has become a prime area of concern due to its high concentration of satellites and debris. The increasing number of near-miss collisions and actual collisions between objects in space underscores the urgency of addressing this issue promptly with both well-conceived rules and proactive missions. Even as the asymmetric advantage the United States and its allies currently enjoy is being challenged by both China and Russia, rapidly expanding space debris has the potential to undermine critical U.S. space capabilities, thus aiding the nation's global competitors.[2] Orbital debris is a threat to U.S. space superiority.

Figure 1. The Growing Threat of Space Debris



Source: ESA

Table 1. The Case for International Cooperation

Benefit	Description
Working Toward a Collective Interest and Common Goals	All spacefaring nations and those aspiring to obtain space capabilities have a vested interest in reducing the risks posed by space debris.
Leveraging Diverse Expertise	Collaborative efforts allow for the pooling of technical know-how, research advancements, and engineering prowess from different countries.
Sharing Costs and Maximizing Resource Efficiency	Sharing the costs among multiple nations alleviates the strain on any single country's budget and by pooling resources, countries can avoid duplication of efforts and streamline research and development processes.
Reaping Diplomatic and Security Benefits	Collaboration can be a diplomatic tool to foster peaceful relationships and build trust among participating nations, while also reducing the ability of these nations to develop counterspace systems or take provocative actions under the guise of active debris removal.
Demonstrating Leadership	Leading by example can set a precedent for responsible and ethical space behavior, inspiring nations worldwide to contribute to the preservation of space as a safe and sustainable environment.
Managing Crises and Preventing Conflict	By collaborating on debris cleanup, countries can jointly manage and mitigate the risks of such incidents, preventing them from evolving into full-blown conflicts.
Promoting Best Practices in Space Operations and Leading in International Norms and Standards	A collective commitment to responsible space operations fosters a culture of sustainability and safety, preventing the creation of new debris and promoting the responsible disposal of defunct satellites.
Facilitating Space Exploration and Innovation	A cleaner space environment facilitates future exploration missions, enabling safer passage through congested regions and reducing the risks faced by spacecraft en route to distant destinations.
Fostering the Policy and Regulatory Environment That Enables a Competitive and Burgeoning U.S. Commercial Space Sector	Active debris removal (ADR) technology is a new sector in which the United States can lead, and technology necessary to conduct the complex mission of approaching, docking, and handling another spacecraft opens much wider markets for in-space servicing, assembly, and manufacturing.
Preserving Space for Future Generations	The Kessler Syndrome, a scenario in which a cascading collision of debris creates a self-sustaining chain reaction that could render certain orbits unusable for centuries, has begun with the exponential growth of debris.

The Case for International Cooperation

Space is a global common, and the challenges posed by space debris require international cooperation. No single nation can resolve this problem unilaterally, making collaboration essential for devising effective solutions. Space debris knows no borders, and its impact extends beyond the territories of any single nation. It affects every spacefaring country and poses risks to both governmental and commercial satellites. As such, dealing with this pressing issue necessitates a collaborative and coordinated global effort. Engaging other nations in a concerted space debris cleanup program is vital for several reasons:

WORKING TOWARD A COLLECTIVE INTEREST AND COMMON GOALS

Space exploration and utilization has often transcended geopolitical boundaries, with nations coming together to achieve shared objectives. Initiating a space debris cleanup program is a natural extension of this spirit of collaboration. All spacefaring nations and those aspiring to obtain space capabilities have a vested interest in reducing the risks posed by space debris. By working together, countries can establish common goals aimed at improving space safety and long-term sustainability.

LEVERAGING DIVERSE EXPERTISE

Every nation brings unique expertise, resources, and capabilities to the table. Collaborative efforts allow for the pooling of technical know-how, research advancements, and engineering prowess from different coun-

tries. Leveraging these diverse strengths can expedite the development of innovative solutions for space debris removal, tracking, and collision avoidance. Scientific cooperation often transcends political boundaries and offers a neutral ground for nations to collaborate. Engaging in a space debris cleanup program emphasizes the diplomacy of science and technology, where nations come together for a common purpose despite their political differences. This collaboration can create lasting bonds among scientists, engineers, and policymakers, fostering an environment of scientific cooperation in the future.

SHARING COSTS AND MAXIMIZING RESOURCE EFFICIENCY

The financial burden of space debris cleanup is substantial, as it requires advanced technology and complex missions. Sharing the costs among multiple nations alleviates the strain on any single country's budget and helps to maximize resource efficiency. Moreover, by pooling resources, countries can avoid duplication of efforts and streamline research and development processes, leading to cost savings and more optimal outcomes. By taking the lead in establishing an international collaboration, the United States will be more able to "drive the train" and select those capabilities most important to national security.

REAPING DIPLOMATIC AND SECURITY BENEFITS[3]

Collaboration in space debris cleanup can transcend mere technical cooperation. It can be a diplomatic tool to foster peaceful relationships and build trust among participating nations. As countries work together toward a common goal, they are more likely to engage in meaningful dialogue, exchange information, and find solutions to other shared challenges. Such increased cooperation in space can have positive spillover effects in other realms of international relations. Space exploration has always captivated the world's imagination, and countries with active space programs often enjoy enhanced soft power and a positive global reputation. Taking the lead in space debris cleanup showcases the United States as a responsible and forward-thinking spacefaring nation committed to global security and sustainability. This positive perception can bolster the United States' soft power and influence on the global stage. It also reduces the chance that nations adversarial to the United States would undertake unilateral missions that might set norms or precedents harmful to U.S. interests, and it reduces the ability of these nations to develop counterspace systems or take provocative actions under the guise of active debris removal.

DEMONSTRATING LEADERSHIP

The United States, as a pioneer in space exploration and technology, has the opportunity to demonstrate global leadership by taking the initiative in space debris cleanup. By promoting a cooperative approach, the United States can influence other spacefaring nations to actively participate in the program. Leading by example can set a precedent for responsible and ethical space behavior, inspiring nations worldwide to contribute to the preservation of space as a safe and sustainable environment.

MANAGING CRISES AND PREVENTING CONFLICT

Space debris collisions have the potential to trigger diplomatic crises or escalate tensions among nations. By collaborating on debris cleanup, countries can jointly manage and mitigate the risks of such incidents, preventing them from evolving into full-blown conflicts.[4] Working together in space-related matters can serve as a confidence-building measure, allowing nations to address potential issues before they escalate.

PROMOTING BEST PRACTICES IN SPACE OPERATIONS AND LEADING IN INTERNATIONAL NORMS AND STANDARDS

Engaging in collaborative space debris cleanup efforts requires adherence to best practices in space operations and responsible space debris management. By setting an example of effective debris mitigation and removal, the United States can encourage other space-faring nations to adopt similar practices. A collective commitment to responsible space operations fosters a culture of sustainability and safety, preventing the creation of new debris and promoting the responsible disposal of defunct satellites. By initiating a collaborative space debris cleanup program, the United States can take a leadership role in developing international norms and standards for responsible space activities.[5] This includes creating guidelines for debris mitigation, collision avoidance, and sustainable space operations. Promoting these standards globally ensures a consistent and coherent approach to space sustainability, strengthening the overall stability

of the space domain. To date the United States has not backed up words with actions.

FACILITATING SPACE EXPLORATION AND INNOVATION

Space debris not only poses a threat to existing space assets but also inhibits future space exploration missions. As humanity sets its sights on the Moon, Mars, and beyond, it is essential to address the challenges posed by debris in high-traffic orbits. A cleaner space environment facilitates future exploration missions, enabling safer passage through congested regions and reducing the risks faced by spacecraft en route to distant destinations.

FOSTERING THE POLICY AND REGULATORY ENVIRONMENT THAT ENABLES A COMPETITIVE AND BURGEONING U.S. COMMERCIAL SPACE SECTOR

The continued growth of a vibrant commercial sector requires a safe operating environment. Moreover, active debris removal (ADR) technology is a new sector in which the United States can lead, and technology necessary to conduct the complex mission of approaching, docking, and handling another spacecraft opens much wider markets for in-space servicing, assembly, and manufacturing. These same technologies have clear national security applications. Thus, the United States should be proactive in creating a domestic ADR industry.

The Hazards of Space Debris: A Case Study

The U.S. Department of Defense Space Surveillance Network currently tracks over 25,000 catalogued objects[1]– nearly two-thirds of which are classified as spent rocket bodies and other debris. There are many more objects that are considered space junk that are not tracked due to their small size but that nonetheless pose a threat to satellites and other spaceborne assets. The existence of anthropogenic or human-made debris of various sizes is a result of more than 600 confirmed fragmentation events recorded since the beginning of the space age.[2] Some events are classified as accidental, others as deliberate. Regardless of intent, these separation events leave behind fragments that are hazardous to critical space activity and infrastructure.

A fairly recent example is the confirmed intentional destruction of Cosmos 1408 in the early hours of November 15, 2021.[3] A nearly 2-ton derelict Soviet electronic and signals intelligence (ELINT) Tselina-D-class spacecraft was successfully targeted and hit by Russian direct-ascent anti-satellite weaponry. The Russian test resulted in the catastrophic destruction of Russia's own 1982 ELINT relic, which generated more than 1,500 pieces of trackable orbital debris and another estimated hundreds of thousands of pieces of smaller debris.[4]

To date, civil government actions—notably including the International Space Station's 5-minute, 5-second maneuver—have been necessary to avoid collisions with Cosmos 1408 debris. As reported to the Federal Communications Commission more than six months after the incident, commercial satellite fleet operations have been impacted, requiring more maneuvering on the order of 1,700 times, which is said to be greater than for any other objects in space.[5] Although the Cosmos 1408 event was the result of a "test," this incident is one of many that underscore the seriousness and ongoing high risk of unmanaged orbital debris.

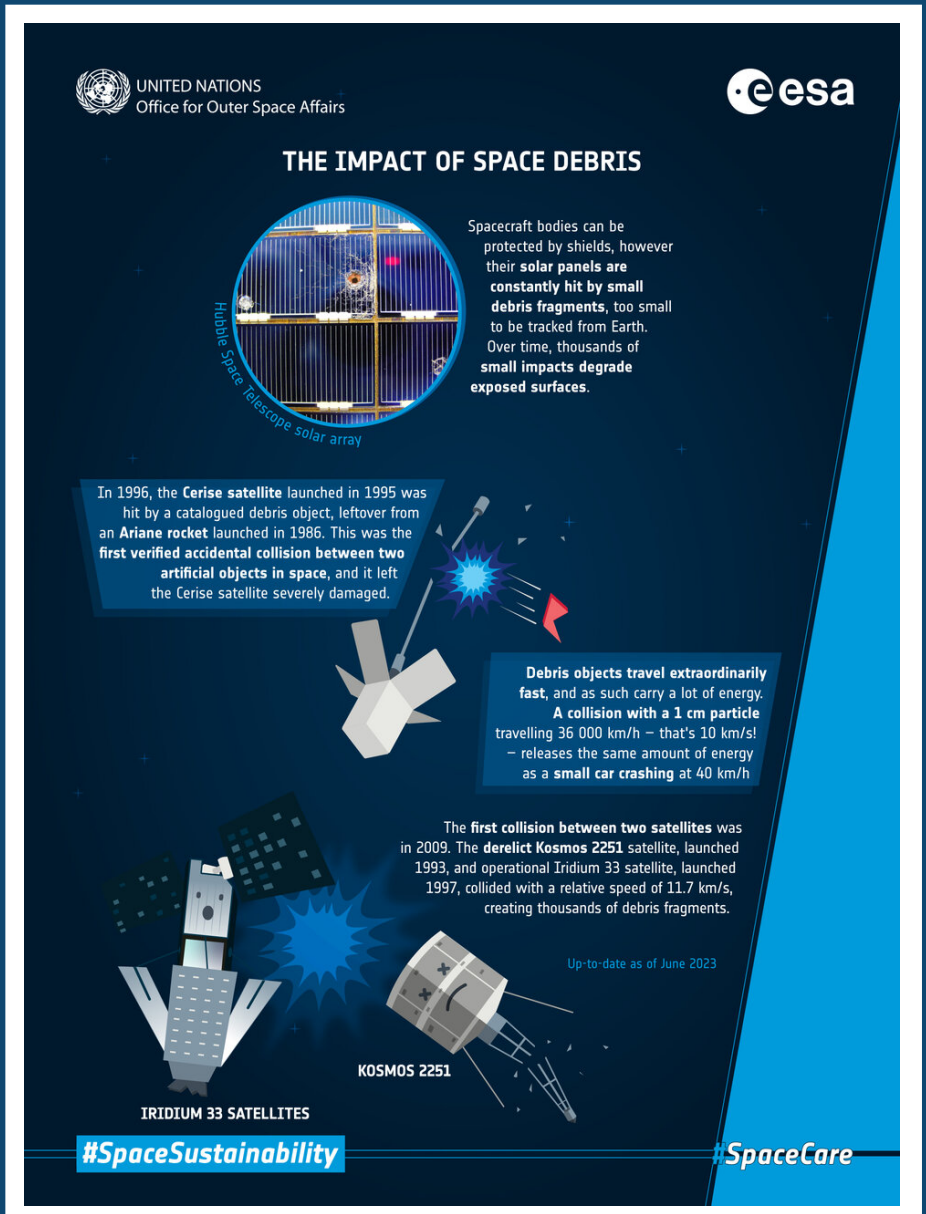
1. (NASA) *Orbital Debris Quarterly News*, 26, no. 2 (June 2022), https://orbitaldebris.jsc.nasa.gov/quarterly-news/pdfs/odqnv26i2.pdf.
2. *ESA's Annual Space Environment Report* (2022), https://www.esa.int/Space_Safety/Space_Debris/ESA_s_Space_Environment_Report_2022.
3. (NASA) *Orbital Debris Quarterly News*, 26, no. 1 (March 2022), https://orbitaldebris.jsc.nasa.gov/quarterly-news/pdfs/odqnv26i1.pdf.
4. U.S. Space Command, "Russian Direct-Ascent Anti-satellite Missile Test Creates Significant, Long-Lasting Space Debris," November 15 2021, https://www.spacecom.mil/Newsroom/News/Article-Display/Article/2842957/russian-direct-ascent-anti-satellite-missile-test-creates-significant-long-last/.
5. Michael Kan, "Starlink Satellites Still Dodging Orbital Debris From Russian Missile Test," *PCMag*, July 5, 2022, https://www.pcmag.com/news/starlink-satellites-still-dodging-orbital-debris-from-russian-missile-test.

PRESERVING SPACE FOR FUTURE GENERATIONS

The consequences of inaction regarding space debris are dire. The Kessler Syndrome, a scenario in which a cascading collision of debris creates a self-sustaining chain reaction that could render certain orbits unusable for centuries, has begun with the exponential growth of debris. Active debris removal (ADR) can significantly mitigate this uncontrolled growth.[6] By undertaking a collective effort to remove debris and prevent further cluttering of space, current generations can ensure that future generations inherit a space environment conducive to continued exploration and progress.

Space debris poses an unprecedented challenge that requires a united response from the international community. Engaging other nations in a comprehensive space debris cleanup program aligns with the principles of shared responsibility, promotes diplomatic ties, and fosters global cooperation in the pursuit of a secure and sustainable space environment. By leading the charge in this endeavor, the United States can exemplify responsible space stewardship and pave the way for a more prosperous and secure space-faring future while shaping policy, perceptions, and technical geography.

Figure 2. The Impact of Space Debris



Source: ESA

Benefits of Space Debris Cleanup: Enhanced Space Security and Shaping Space Traffic Management

Enhancing space security through a global space debris cleanup program is a crucial aspect of protecting vital space assets, reducing collision risks, and fostering resilience in space systems. By actively participating in such a program, the United States can play a leading role in promoting responsible space behavior, strengthening international space security cooperation, and ensuring the continued safe and sustainable use of outer space. Initiating and/or engaging in a global space debris cleanup program can enhance space security and pave the road to U.S. Space Traffic Management (STM) in the following ways:

PROTECTING OPERATIONAL SATELLITES

Operational satellites are essential for communication, navigation, weather monitoring, national defense, and a host of other applications. These satellites are vital assets that play a crucial role in modern life and national security. By removing defunct satellites and debris from critical orbits, the risk of collisions with operational satellites is significantly reduced, safeguarding these vital assets from potential damage or disruption. A coordinated space debris cleanup program actively reduces the density of debris, minimizing the probability of collisions and the potential for further catastrophic events.

SAFEGUARDING SPACE ASSETS AND SAFEGUARDING RESILIENCE

Space missions and satellite deployments involve significant financial investments. Protecting these investments from the threat of space debris is crucial for both government agencies and private companies. By participating in a global cleanup program, the United States can help ensure that space assets operate in a less hazardous environment, providing better returns on investments and extending the operational life of satellites. Resilience is a fundamental aspect of space security. Ensuring that space systems can withstand and recover from potential disruptions, whether caused by natural events or collisions with space debris, is essential. Space debris cleanup contributes to this resilience by reducing the likelihood of collisions that could lead to system failures. Strengthening the resilience of space assets ensures continuity in critical services, such as navigation, communication, and disaster response.

FACILITATING SPACE SITUATIONAL AWARENESS

Table 2. The Benefits of Space Debris Cleanup

Benefit	Description
Protecting Operational Satellites	By removing defunct satellites and debris from critical orbits, the risk of collisions with operational satellites is significantly reduced, safeguarding these vital assets from potential damage or disruption.
Safeguarding Space Assets and Increasing Resilience	Ensuring that space systems can withstand and recover from potential disruptions, whether caused by natural events or collisions with space debris, is essential—strengthening the resilience of space assets ensures continuity in critical services, such as navigation, communication, and disaster response.
Facilitating Space Situational Awareness (SSA)	Space debris cleanup can alleviate the density of objects in critical orbits, enabling more accurate and reliable SSA data, which is essential for collision avoidance and effective space traffic management.
Deconflicting Space Missions	Engaging in a space debris cleanup program fosters communication and collaboration among spacefaring nations, allowing for better coordination of mission trajectories and orbital slots.
Managing Satellite Constellations and Space Traffic	Establishing common guidelines for collision avoidance maneuvers, safe disposal of defunct satellites, and notification procedures for close approaches fosters a harmonized and consistent approach to space traffic management.
Encouraging Workforce Development for Emerging Global Industry	There are jobs and industries relating to space waste management in which the United States can lead.

Space situational awareness (SSA) refers to the ability to accurately track and predict the positions of objects in space, including satellites and debris. A cluttered space environment can make SSA challenging, leading to uncertainties in tracking space objects and predicting potential close approaches. Space debris cleanup can alleviate the density of objects in critical orbits, enabling more accurate and reliable SSA data, which is essential for collision avoidance and effective space traffic management. A collaborative space debris cleanup program involves the cataloging and tracking of removed debris and defunct satellites. This effort contributes to a comprehensive space object database, facilitating better tracking and identification of objects in space. A more robust and up-to-date catalog allows for more precise orbital predictions and collision risk assessments, enhancing space traffic management capabilities.

DECONFLICTING SPACE MISSIONS

As the number of satellites and space missions grows, there is an increasing need to coordinate and deconflict planned launches and maneuvers. Engaging in a space debris cleanup program fosters communication and collaboration among space-faring nations, allowing for better coordination of mission trajectories and orbital slots. A cleaner space environment minimizes the risk of unintentional collisions and close approaches between spacecraft.

MANAGING SATELLITE CONSTELLATIONS AND SPACE TRAFFIC

Satellite constellations, such as those used for global communications and Earth observation, are becoming more prevalent. Managing the orbits and positions of satellites within these constellations requires careful planning and coordination. A collaborative effort in space debris cleanup can help optimize the placement of satellites within constellations, ensuring minimal interference and collision risks between satellites. A globalspace debris cleanup program provides an opportunity for participating nations to standardize space traffic procedures and protocols. Establishing common guidelines for collision avoidance maneuvers, safe disposal of defunct satellites, and notification procedures for close approaches fosters a harmonized and consistent approach to space traffic management. These standardized procedures contribute to a safer and more efficient space environment for all.

ENCOURAGING WORKFORCE DEVELOPMENT FOR EMERGING GLOBAL INDUSTRY

There are jobs and industries relating to space waste management in which the United States can lead.

Space debris cleanup plays a pivotal role in enhancing space traffic management. By reducing the risks of collisions, improving space situational awareness, and promoting standardized procedures, a collaborative space debris cleanup program can contribute to a safer and more sustainable space environment. Effective space traffic management is crucial for ensuring the continued success of space missions, satellite services, and scientific exploration in the increasingly crowded realm of space.

Challenges and Obstacles

Addressing the challenges posed by space debris requires the development and deployment of advanced technologies for debris removal, tracking, and collision avoidance. As space debris varies in size, shape, and orbital characteristics, designing effective and versatile cleanup systems is a formidable task. The successful implementation of a global space debris cleanup program hinges on overcoming a range of technological hurdles. Advancing tracking capabilities, developing versatile debris capture technologies, conducting active debris removal missions, and enhancing space situational awareness are among the key areas that require focused research and development. With sustained investment in innovative technologies and international cooperation, these challenges can be met, paving the way for a safer, secure, and sustainable space environment for current and future generations. Key technological hurdles must be overcome to successfully implement a global space debris cleanup program, including:

ADVANCING DEBRIS IDENTIFICATION AND TRACKING

Accurate identification and tracking of space debris are critical for effective cleanup operations. The vast number of objects in space, ranging from small fragments to defunct satellites, requires sophisticated tracking systems and algorithms. Developing advanced sensors, ground-based radars, and space-based telescopes capable of precisely detecting and characterizing space debris is essential for successful cleanup missions. Such sensors also help advance U.S. national security by increasing our ability to surveil for hostile or aggressive actions and enhance de-

Table 3. Technological Hurdles

Challenge	Description
Advancing Debris Identification and Tracking	Developing advanced sensors, ground-based radars, and space-based telescopes capable of precisely detecting and characterizing space debris is essential for successful cleanup missions.
Developing Debris Capture and Removal Technologies	Dealing with larger objects, such as old satellites or spent upper rocket stages, may require robotic arms, nets, or other capture mechanisms—similarly, smaller debris particles might necessitate technologies like electrodynamic tethers or ion beams for deorbiting.
Conducting Active Debris Removal Missions	These missions require precise orbital maneuvering and propulsion systems to safely deorbit the debris without creating additional fragments or endangering operational satellites.
Enhancing Space Situational Awareness (SSA)	Enhancing SSA capabilities is crucial for both collision avoidance and effective debris cleanup, which includes improving ground-based tracking systems, increasing the number of space-based telescopes, and developing advanced algorithms for data processing and collision prediction.
Deorbiting Defunct Satellites	Implementing effective deorbiting strategies for end-of-life satellites, such as propulsive maneuvers or drag sails, requires careful planning and coordination with satellite operators.
Developing Autonomous Operations and Robotics	Advanced robotics and artificial intelligence are essential for executing tasks like debris capture, attachment, and deorbiting—developing autonomous systems that can operate safely and effectively in the harsh environment of space is a significant technological challenge.

terrence by preventing operational surprise.[7] They also increase our sensing capabilities to and preparedness to cope with near-Earth-object hazards.[8]

DEVELOPING DEBRIS CAPTURE AND REMOVAL TECHNOLOGIES

The diverse nature of space debris demands versatile capture and removal technologies. Dealing with larger objects, such as old satellites or spent upper rocket stages, may require robotic arms, nets, or other capture mechanisms. Similarly, smaller debris particles might necessitate technologies like electrodynamic tethers or ion beams for deorbiting. Research and development efforts must focus on creating adaptable and efficient debris removal mechanisms to handle various debris types. Maturing these technologies simultaneously advances core competencies to meet U.S. goals for the development of in-space servicing, assembly, and manufacturing.[9]

CONDUCTING ACTIVE DEBRIS REMOVAL MISSIONS

Conducting active debris removal missions involves rendezvousing with non-operational objects and safely capturing them for controlled deorbiting or disposal. Developing spacecraft capable of autonomously approaching and securely attaching to debris objects is complex. These missions also require precise orbital maneuvering and propulsion systems to safely deorbit the debris without creating additional fragments or endangering operational satellites.

DEORBITING DEFUNCT SATELLITES

Deorbiting defunct satellites that have reached the end of their operational life is crucial to preventing the buildup

of space debris. Implementing effective deorbiting strategies for end-of-life satellites, such as propulsive maneuvers or drag sails, requires careful planning and coordination with satellite operators. Additionally, it necessitates ensuring that defunct satellites can be remotely controlled or automatically programmed for controlled reentry.

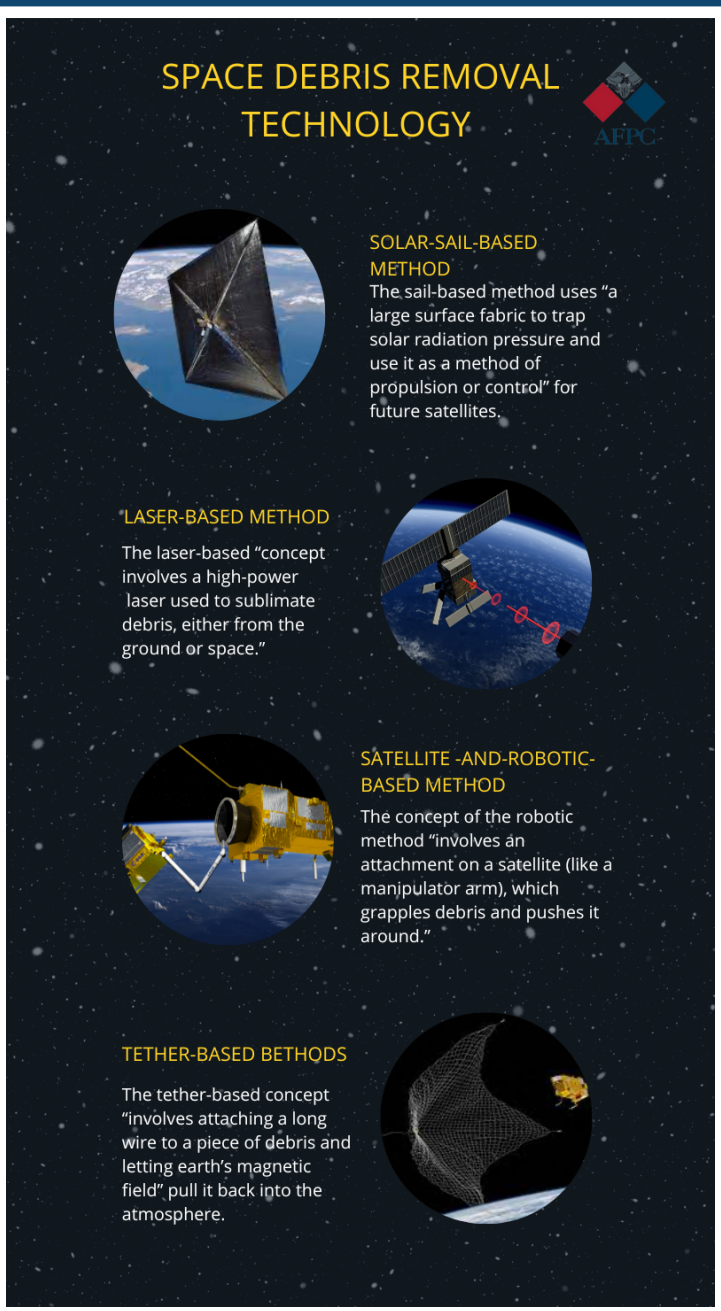
ENHANCING SPACE SITUATIONAL AWARENESS

Enhancing SSA capabilities is crucial for both collision avoidance and effective debris cleanup. This includes improving ground-based tracking systems, increasing the number of space-based telescopes, and developing advanced algorithms for data processing and collision prediction. A more comprehensive SSA network enables better decision-making for debris capture missions and reduces the risk of collisions during cleanup operations.

DEVELOPING AUTONOMOUS OPERATIONS AND ROBOTICS

Many debris cleanup missions will require autonomous spacecraft capable of performing complex operations in space without direct human intervention. Advanced robotics and artificial intelligence are essential for executing tasks like debris capture, attachment, and deorbiting. Developing autonomous systems that can operate safely and effectively in the harsh environment of space is a significant technological challenge.

Figure 3. Technologies for Space Debris Mitigation



Source: American Foreign Policy Council

Funding and Resource Allocation Challenges

Undertaking a comprehensive space debris cleanup program is a resource-intensive endeavor, involving financial investments, research and development efforts, and international cooperation. Funding and resource allocation represent one challenge to overcome when initiating a U.S.-led cleanup initiative. Several key aspects must be addressed to ensure the successful implementation of the program:

COST ESTIMATION AND FINAL COMMITMENT

The first step in tackling the funding challenge is to estimate the overall cost of the cleanup program. This estimation should include the expenses associated with technology development, mission planning, spacecraft deployment, ground-based infrastructure, and ongoing monitoring and coordination efforts. Governments, space agencies, and private entities involved in space activities must commit the necessary financial resources to

support the program effectively. NASA has provided an excellent starting point from which to build, in the recent publication led by Thomas Colvin, *Cost and Benefit Analysis of Orbital Debris Removal.*[10]

MULTILATERAL INTERNATIONAL FUNDING

Given that space debris affects the interests of all space-faring nations, the financial burden should be shared among multiple stakeholders. Establishing multilateral funding mechanisms, where participating nations contribute according to their space capabilities and activities, can distribute the costs more equitably. This approach fosters a sense of shared responsibility and encourages all nations with space assets to participate in the cleanup effort. The United States must engage in diplomatic negotiations to define a fair and transparent framework for cost -sharing. This involves discussing contributions based on gross domestic product (GDP), space assets, and involvement in space activities. Transparency in financial commitments fosters trust among nations and strengthens overall cooperation in the cleanup program.

EXISTING AGREEMENTS AND ORGANIZATIONS

Building on existing space-related agreements and organizations can streamline the funding process and coordination efforts. Leveraging frameworks such as the United Nations Committee on the Peaceful Uses of Outer Space (COPUOS) or the Inter-Agency Space Debris Coordination Committee (IADC) can facilitate cooperation and resource allocation. Existing international agreements can provide a basis for defining the roles and responsibilities of participating nations in the cleanup program.

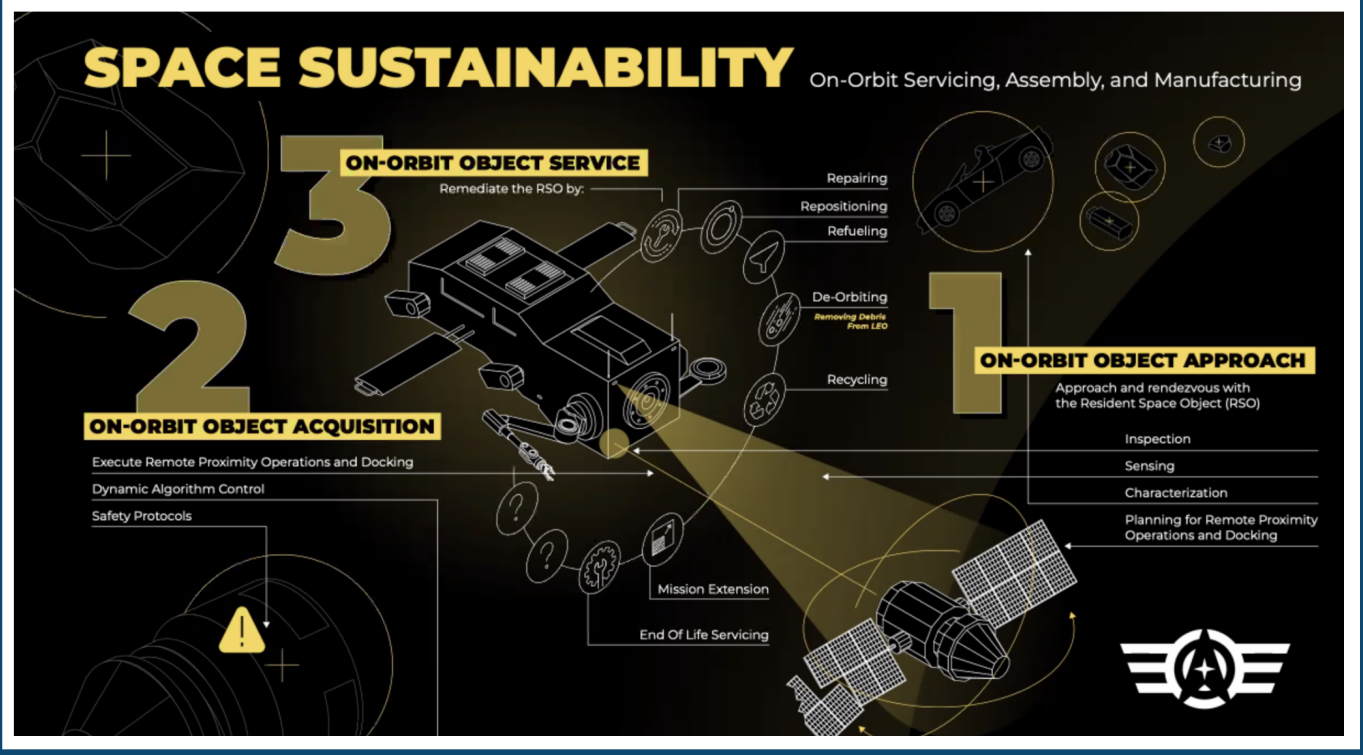
PUBLIC-PRIVATE PARTNERSHIPS AND COMMERCIAL INCENTIVES

Engaging the private sector through public-private partnerships can be instrumental in funding and implementing space debris cleanup missions. Private companies involved in space operations have a vested interest in debris mitigation, as it directly impacts the safety and functionality of their satellite constellations and future space missions. Collaborating with private entities can bring additional expertise, resources, and funding to the cleanup program. The U.S. Space Force SpaceWERX Orbital Prime administered within the Small Business portfolio is an excellent example of encouraging public-private partnerships. Creating commercial opportunities and incentives for space debris removal can help attract private investments and support from the commercial space sector. Governments can offer contracts or rewards for private companies that successfully remove debris or develop innovative cleanup technologies. These incentives

Table 4. Funding and Resource Allocation Challenges

Challenge	Description
Cost Estimation and Financial Commitment	An estimation of the overall cost of the cleanup program should include the expenses associated with technology development, mission planning, spacecraft deployment, ground-based infrastructure, and ongoing monitoring and coordination efforts.
Multilateral International Funding	Establishing multilateral funding mechanisms, where participating nations contribute according to their space capabilities and activities, can distribute the costs more equitably.
Existing Agreements and Organizations	Leveraging frameworks such as the United Nations Committee on the Peaceful Uses of Outer Space (COPUOS) or the Inter-Agency Space Debris Coordination Committee (IADC) can facilitate cooperation and resource allocation.
Public-Private Partnerships and Commercial Incentives	Collaborating with private entities can bring additional expertise, resources, and funding to the cleanup program—governments can offer contracts or rewards for private companies that successfully remove debris or develop innovative cleanup technologies.
Cost of Space Waste Management	The U.S. government total space expenditures from civil, military, and intelligence agencies are estimated to be $70 billion per year, which translates to an allocation of approximately $600 million per year toward operational space waste management.

Figure 4. Space Sustainability



Source: Space News

encourage private-sector involvement in the cleanup program and stimulate the development of cost-effective and scalable solutions.

COST OF SPACE WASTE MANAGEMENT

The United States spends approximately $200 billion each year on waste management or about 0.87 percent of GDP. With the 2021 U.S. space economy of approximately $211 billion per year, the proportional spending on space waste management should be about $1.8 billion per year from all U.S. sources.[11] The U.S. government total space expenditures from civil, military, and intelligence agencies are estimated to be $70 billion per year, which translates to an allocation of approximately $600 million per year toward operational space waste management.

Funding and resource allocation are central challenges in initiating and sustaining a global space debris cleanup program. Estimating the costs, establishing multilateral funding mechanisms, engaging in public-private partnerships, fostering international collaboration, leveraging existing agreements, and providing commercial incentives including possible fines or penalties are all essential components of addressing this financial challenge. Insurance companies have not yet developed policies for satellite service companies but are looking at this possible emerging market. By investing in space debris cleanup, nations can ensure the security and sustainability of space activities, promoting the long-term benefits of space exploration and utilization.

Proposed Framework for a Collaborative Space Debris Cleanup Program

The European Space Agency, the Japanese Aerospace Exploration Agency, the U.K. Space Agency, and others have established orbital debris programs. *The United States is behind and needs to initiate a significant program to pursue this noble aim.* NASA and various academic institutions have studied the problem and have collectively begun the needed technical assessment of the totality of the problem we face, a first and necessary step toward finding a solution. SpaceWERX Orbital Prime, although a good start to provide seed corn to the robust U.S. innovation community, is not sufficient alone to pursue these important ob-

jectives. Legislation is necessary. Bills like the ORBITS Act are a good start, but they should include funding. Building on the NASA report, the following recommendations should be pursued:

1. Congress should express its sense that the United States should lead a domestic ADR industry (and codify the responsibilities of the president to promote such a program) and lead in establishing an international program.
2. The House Armed Services Committee and the Senate Armed Services Committee should allocate no less than $600 million over the Future Years Defense Program to U.S. Space Force research and development to develop multiple demonstration missions (PE 1206616SF) in partnership with commercial industry and private capital.
3. The House Strategic Forces Subcommittee and the Senate Armed Services Committee should consider providing no less than $600 million from fiscal years 2026 to 2030 for the U.S. Space Force to develop prototype systems for active debris remediation in partnership with industry.
4. The House Committee on Science, Space, and Technology should create a program element (PE) specific to NASA to fund future research, initiatives, and space demonstration missions addressing orbital debris for NASA and the Department of Commerce and provide no less than $250 million over the future years Defense Program to be allocated to NASA for maturing ADR technology.
5. The Senate Commerce, Science, and Transportation Committee should assess the structure by which optimal allocation of costs would be assigned and review the policies associated with the responsibility for U.S.-flagged satellite companies to remove or dispose of their systems at end-of-life or face fines and penalties.

Conclusion

The threat posed by space debris is a pressing issue requiring immediate action and collaboration. As a space superpower, the United States has a unique opportunity to lead the global community in a comprehensive space debris cleanup program. By taking on this role, the United States can safeguard its space interests, promote peaceful space activities, and foster cooperation and goodwill among nations. Embracing this challenge will be a milestone in ensuring the sustainability and securityof our shared orbital environment and the future of space exploration.

Endnotes

[1] A Brief History of Space Debris," Aerospace Corporation, November 2, 2022, https://aerospace.org/article/brief- history-space-debris.

[2] Defense Intelligence Agency, *Challenges to Security in Space*, 2022, https://www.dia.mil/Portals/110/Documents/News/Military_Power_Publications/Challenges_Security_Space_2022.pdf.

[3] "The United States will increase efforts to mitigate, track, and remediate space debris. The United States will advance development and implementation of domestic and international best practices to mitigate the creation of space debris and will support efforts to evolve those practices to ensure continued safety of flight operations in the future.… U.S. regulations must provide clarity and certainty for the authorization and continuing supervision of non-governmental space activities, including for novel activities such as on-orbit servicing, orbital debris removal, space-based manufacturing, commercial human spaceflight, and recovery and use of space resources." *U.S. Space Priorities Framework*, https://www.whitehouse.gov/wp- content/uploads/2021/12/united-states-space-priorities-framework-_-december-1-2021.pdf. "Meet existing international obligations and showcase U.S. transparency and engagement on coordination with other States on registration of space objects, astronaut rescue and return, debris recovery, and planetary protection and defense.… Building upon general international guidelines on space debris and mitigation and long-term sustainability, work to reduce risks of misunderstanding, help prevent or manage space-related incidents, and prevent inadvertent escalations." *U.S. Strategic Framework for Space Diplomacy Framework*, https://www.state.gov/wp-content/uploads/2023/05/Space-Framework-Clean- 2-May-2023-Final-Updated-Accessible-5.25.2023.pdf.

[4] Peter Garretson, Alfred B. Anzaldúa, and Hoyt Davidson, "Catalyzing Space Debris Removal, Salvage, and Use," *Space Review*, December 9, 2019, https://www.thespacereview.com/article/3847/1.

[5] Peter Garretson, "An ICAO for the Moon: It's Time for an International Civil Lunar Organization," *Space Review*, July 11, 2022, https://www.thespacereview.com/article/4419/1.

[6] Thomas J. Colvin, John Karcz, and Grace Wusk, *Cost and Benefit Analysis of Orbital Debris Remediation*, NASA, March 10, 2023, https://www.nasa.gov/sites/default/files/atoms/files/otps_- _cost_and_benefit_analysis_of_orbital_debris_remediation_-_final.pdf.

[7] Peter Garretson and Chance Saltzman, Space Strategy Podcast, "Gen. Chance Saltzman: Competitive Endurance, Proposing a 'Theory of Success' for the Space Domain," American Foreign Policy Council, August 23, 2023, https://podcasts.apple.com/us/podcast/40-gen-chance-saltzman-competitive-endurance-proposing/id1559865448?i=1000625449118.

[8] National Science and Technology Council, *National Preparedness Strategy & Action Plan for Near-Earth Object Hazards and Planetary Defense*, White House, April 2023, https://www.whitehouse.gov/wp-content/uploads/2023/04/2023-NSTC- National-Preparedness-Strategy-and-Action-Plan-for-Near-Earth-Object-Hazards-and-Planetary-Defense.pdf.

[9] National Science and Technology Council, *In-Space Servicing, Assembly, and Manufacturing National Strategy*, White House, April 2022, https://www.whitehouse.gov/wp-content/uploads/2022/04/04-2022-ISAM-National-Strategy-Final.pdf; *National Science and Technology Council, National In-Space Servicing, Assembly, and Manufacturing Implementation Plan*, White House, December 2022, https://www.whitehouse.gov/wp-content/uploads/2022/12/NATIONAL-ISAM- IMPLEMENTATION-PLAN.pdf.

[10] Colvin et al., 2023, *Cost and Benefit Analysis of Orbital Debris Remediation.*

[11] Tina Highfill and Chris Surfield, "U.S. Space Economy, 2012–2021," *The Journal of the U.S. Bureau of Economic Analysis*, June 27, 2023, https://apps.bea.gov/scb/issues/2023/06-june/0623-space- economy.htm#:~:text=The%20updated%20and%20revised%20statistics,and%20360%2C000%20private%20industry%20jobs.

Figure Notes

Figure 1: "Satellites vs space debris," *European Space Agency*, February 10, 2021, https://www.esa.int/Space_Safety/Space_Debris/ESA_UNOOSA_space_debris_infographics_and_podcast.

Figure 2: "The impact of space debris," *European Space Agency,* February 10, 2021, https://www.esa.int/Space_Safety/Space_Debris/ESA_UNOOSA_space_debris_infographics_and_podcast.

Figure 3: "Solar Sail Demonstrator ('Sunjammer')", NASA, https://www.nasa.gov/mission_pages/tdm/solarsail/index.html; "Active debris removal", *European Space Agency*, https://www.esa.int/Space_Safety/Space_Debris/Active_

debris_removal; "e-Deorbit's robotic arm", European Space Agency, January 18, 2017, https://www.esa.int/ESA_Multimedia/Images/2017/01/e.Deorbit_s_robotic_arm; "Space Debris: Catch It If We Can", *European Space Agency*, https://blogs.esa.int/cleanspace/2017/02/09/space-debris-catch-it-if-we-can/.
Figure 4: "Space Force launches 'Orbital Prime' program to spur market for on-orbit services," *Space News*, November 4, 2021, https://spacenews.com/space-force-launches-orbital-prime-program-to-spur-market-for-on- orbit-services/.

The author would like to thank Ms. Stacey Jones, CEO of O Analytics, for preparing The Hazards of Space Debris: A Case Study *portion of the paper, as well as, Kyle Wilgus and Zane Kuecks for their graphic design support. Additional thanks go to Jim Shell, Peter Garretson, and Richard Harrison for their project support.*

AMERICAN FOREIGN POLICY COUNCIL

Space Policy Review

ABOUT THE SPACE POLICY INITIATIVE

For America, space represents the next great strategic frontier. Yet the United States now faces growing competition in that domain from countries like Russia and China, each of which are developing technologies capable of targeting U.S. space assets. As such, defining a strategy for ensuring space security, sustainability, and commerce needs to be a strategic priority for the U.S. AFPC's top-notch array of experts form a robust team that make a major contribution to crafting space policy by providing policymakers with the ideas and tools they need to chart a course in this emerging domain. For regular insights from space thought leaders tune into SPI's Space Strategy podcast (available at https://anchor.fm/afpcspacepod). SPI co-directors: Richard M. Harrison and Peter A. Garretson

ABOUT AFPC

For more than four decades, AFPC has played an essential role in the U.S. foreign policy debate. Founded in 1982, AFPC is a 501(c)(3) non-profit organization dedicated to bringing information to those who make or influence the foreign policy of the United States and to assisting world leaders with building democracies and market economies.

AFPC is widely recognized as a source of timely, insightful analysis on issues of foreign policy, and works closely with members of Congress, the Executive Branch and the policymaking community. It is staffed by noted specialists in foreign and defense policy, and serves as a valuable resource to officials in the highest levels of government.

AFPC MISSION STATEMENT

The American Foreign Policy Council seeks to advance the security and prosperity of the United States by:

1. Providing primary source information, as well as policy options, to persons and organizations who make or influence the national security and foreign policies of the United States;
2. Arranging meetings and facilitating dialogue between American Statesmen and their counterparts in other countries; and
3. Fostering the acceptance and development of representative institutions and free market economies throughout the world in a manner consistent with the Constitution, the national interest, and the values of the United States.

September 2023 | No. 4 Layout and Graphic Design by Rehna Sheth

AMERICAN FOREIGN POLICY COUNCIL
509 C Street NE, Washington, D.C. 20002 | Telephone: 202.543.1006 | Fax: 202.543.1007 | www.afpc.org