Problem Solving Initiative: Multidisciplinary Recommendations for Space Debris Remediation

FORD SCHOOL ENGINEERING LAW ROSS

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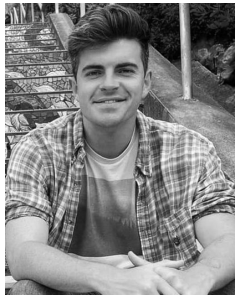

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What is Space Debris?

Space Debris: Any human-made object orbiting Earth that no longer serves any useful purpose

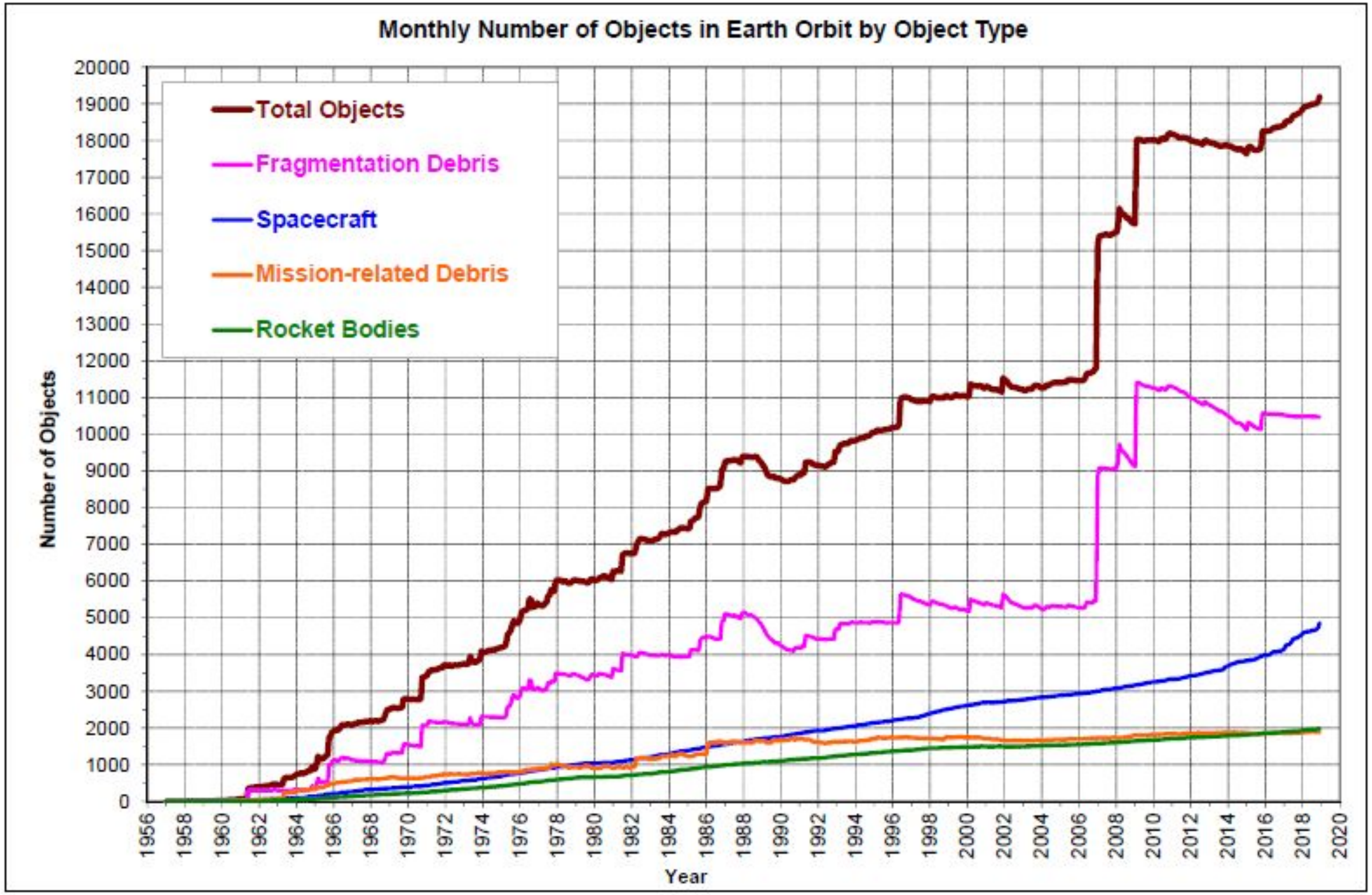
(Colvin, NASA)

Sources:

1. Abandoned rocket stages
2. Abandoned spacecraft
3. Satellite breakup
4. On-orbit collisions

How much Space Debris is there?

Debris Size	Debris Amount
10cm +	~40,000 (~20, 000 known)
1–10 cm	~500,000 – 1,000,000
1–10 mm	100 million+



(NASA Orbital Debris Program Office)

What's been done about the problem?

Primary international focus: mitigation

- European Space Agency's Zero Debris Charter (2024):
    - 12 countries and 40+ companies aiming for no net addition of debris by 2030
- U.S. National Orbital Debris Mitigation Plan (2022)
    - Post-Mission Disposal Guidelines:
        - Deorbit or movement to graveyard orbit required in 5 years after end of life
    - Design and Operational Standards:
        - Minimize debris release during operation, design with deorbit intentions

Despite international collaboration on mitigation efforts, two main elements are lacking:

- No international collaboration with non-United States allies
    - Lacking big space actors like China and Russia
- No current development of mitigation practices or standards

Almost every attempt at solving the issue ends in the same conclusion: international collaboration is needed to address and solve the issue...

Motivations

We do not want: End with common, ambiguous consensus that international discussion is needed ✗

We want: **Initiate tangible, international action by providing workable starting points** ✓

Kessler Syndrome:
Chain reaction of low Earth orbit (LEO) collisions that lead to exponential increase in space debris

- Whether Kessler has already begun has been debated since 1990's
- Rather than analyzing if Kessler has begun or not:
  - We aim to reduce further collisions through our **remediation focus**

Goal: Shift *from* long standing international focus with preventative mitigation *to* effective remediation

- **Mitigation**: preventing future debris from being created
- **Remediation**: removing pre-existing debris that has no plans to come down

Class Objectives:

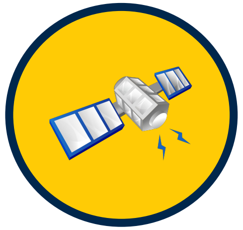
Develop scalable, near-term Active Debris Removal (ADR) solutions & recommendations

Address & reduce space debris

Minimize environmental & diplomatic risks

Intersect engineering, legal, policy, & economic perspectives

Agenda



Engineering Methodology: a layered technical approach to addressing the space debris problem

Funding sources for the issue: A brief overview of our potential approaches to developing international collaboration on funding

Law & Policy Overview: Analyze the current legal framework surrounding the space debris problem and address the gaps that inhibit remediation

ENGINEERING

Technical Overview

We propose a three-tiered remediation framework:

1. Short-term: space-based laser system to remove small debris (1–10 cm)
2. Medium-term: “Pac-Man Method” to capture and return larger debris to Earth for reuse
3. Long-term: in-space salvage zone or “junkyard” to store recoverable materials

Engineering Methodology:

- Selection methodology - what debris to choose for removal
- Constraints - limit and narrow down technology possible to help with issue
- Creativity: applying proven space tech in novel and unconventional scenarios

Selection Methodology + Constraints

Goal: Develop an innovative, achievable system to reduce space debris

Selection Methodology

- **Original plan:** remove 50 most hazardous objects (McKnight)
- **Final plan:** Focus on US and ally-origin debris for access and feasibility
  - Removing 12 well-chosen objects per year (McKnight)
- Atmospheric reentry strategy based on debris size
  - Reentry preferred for small debris due to cost of reuse
  - Medium and large debris prioritized for reuse-based solutions
- Consider ownership, location, and legal status in design choices

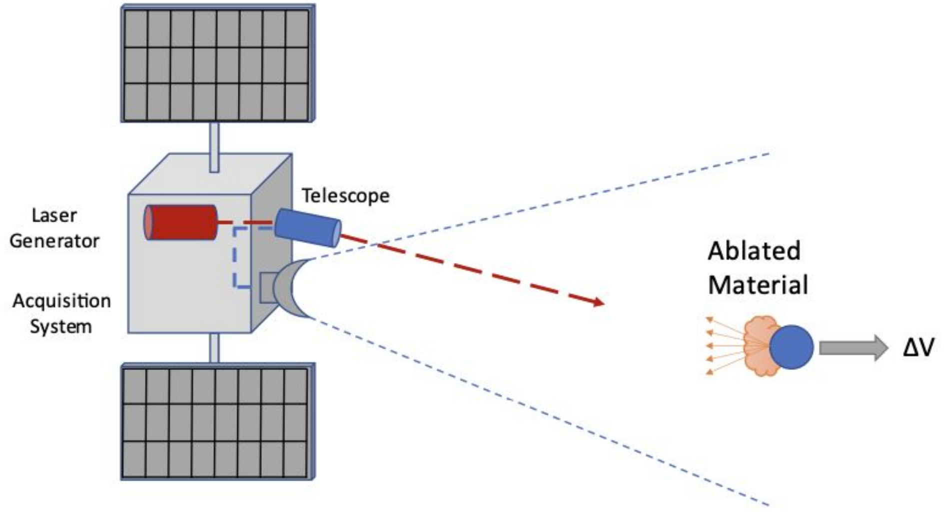
Constraints

- Prefer highest possible TRL technologies to reduce development time and risk
- Solutions must not generate new debris or fragments
- Environmental concerns with atmospheric reentry
- Account for debris spin and detumbling requirements
- Solutions for debris <1 cm is infeasible for tracking and removal

Atmospheric Burn-up Solutions

Solution 1: Space-Based Laser System

- **Concept:** Space-based constellation utilizing pulsed laser ablation to apply thrust via surface ejection
  - Target sub-10 cm debris objects
  - Expand outward from high-debris orbits
- **Why Space-Based:** Avoids atmospheric distortion; enables precise, opportunistic targeting
- **Advantages:** Contactless, scalable, minimizes further debris creation



Source: NASA

- **Technology:** Existing laser/tracking tech; needs in-space integration and testing
- **Risks:** Potential for fragmentation, edge effects; can be mitigated via testing in less populated orbits or UV lasers; pulsed lasers and weaponization risk
- **Timeline:** Can begin development almost immediately
- **Business Case:** Opens up valuable LEO orbits; potential dual-use applications when lasers are idle; $15M–$150M to remove 50,000 debris pieces (NASA)

Solution 1: Regulations, Policy Considerations

- **NASA Policy Directives (esp. 8715.6E)**
  - Applies to any US orbital debris mitigation activities
  - Requires risk assessments for active debris removal (ADR) systems, including laser ablation
  - Establishes safety baselines, guidance, best-practices, & SOP's for ADR operations
  - **Note**: Safety baselines & SOP's for laser ablation-based ADR systems are incomplete
- **U.S. Laser Clearinghouse (LCH) - Department of Defense**
  - Regulates space-based directed energy systems, mitigates interference with other assets
  - LCH purview is directly related to national security
  - Requires review, approval, and tracking of all above-horizon laser operations (DoD or civilian)
    - Fire/No Fire approval based on time & direction window, written application
    - Approvals are scheduled, registered, continuously deconflicted
- **Policy gaps:**
  - Absence of international coordination requirements
  - No clear economic, liability or escalation guidelines

Reusability-Focused Solutions

Capture Technology: Robotic Arm(s) and Tentacles

Robotic Arm(s)

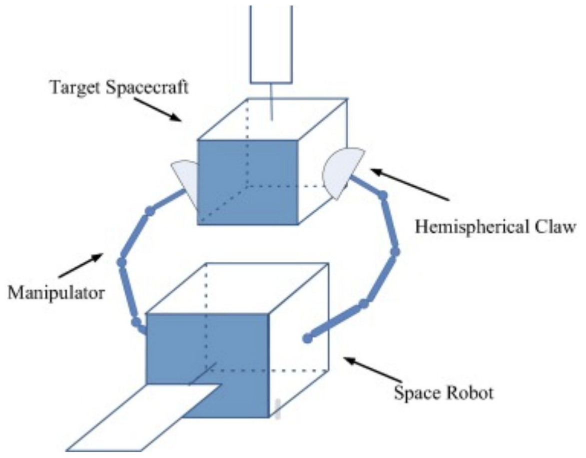
- Single or multi computer controlled mechanical arms attached to a chaser satellite equipped with a gripper end effector used to grip target debris

Tentacles

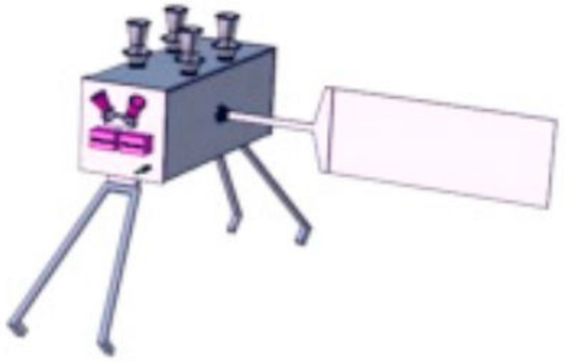
- Tentacle-like gripper arms containing clamping mechanisms attached to a chaser satellite which can grab onto target debris

Detumbling

- Dual robotic arms
- Flexible brush
- Ion Beam Shepherd
- Addition of a robotic arm to tentacle configuration



Example of dual-robotic arm debris capture
Source: Han et al.



ESA's e.Deorbit, with tentacle configuration
Source: Shan et al.

Rendezvous Considerations

- State of the target, in terms of degradation
- Positioning
- Velocity and tumbling
- Quantitative Risk Assessment Tool

Enhancements

- Possibility of adding gecko gripper attachments, mechanical attachments which require no additional force and mimic a gecko's feet to grip onto surfaces

Solution 2: Earth Reentry of Debris (No Atmospheric Burn-Up)

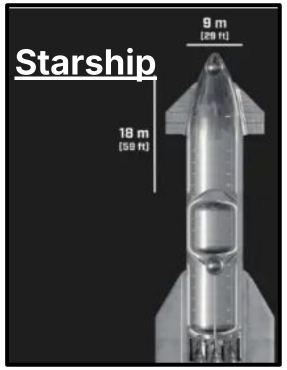
Concept
- Safely returning debris to Earth without atmospheric burnup
- Two potential ways to do this:
    - Re-entry capsules / shields
    - Return to earth in launch vehicles ("Pac-Man" method)

Varda Space Capsule

Re-Entry Capsules / Shields
- Hypersonic reentry of the debris through the atmosphere and safe landing back on Earth and this technology has been validated and has lots of startups within the space
- While it didn't do this for debris per se, it's a type of technology that could be adapted

Return to earth in launch vehicles ("Pac-Man" method)
- Utilizing future upper-stage fully reusable rockets that release their satellite payloads and return to Earth

Radian Aerospace



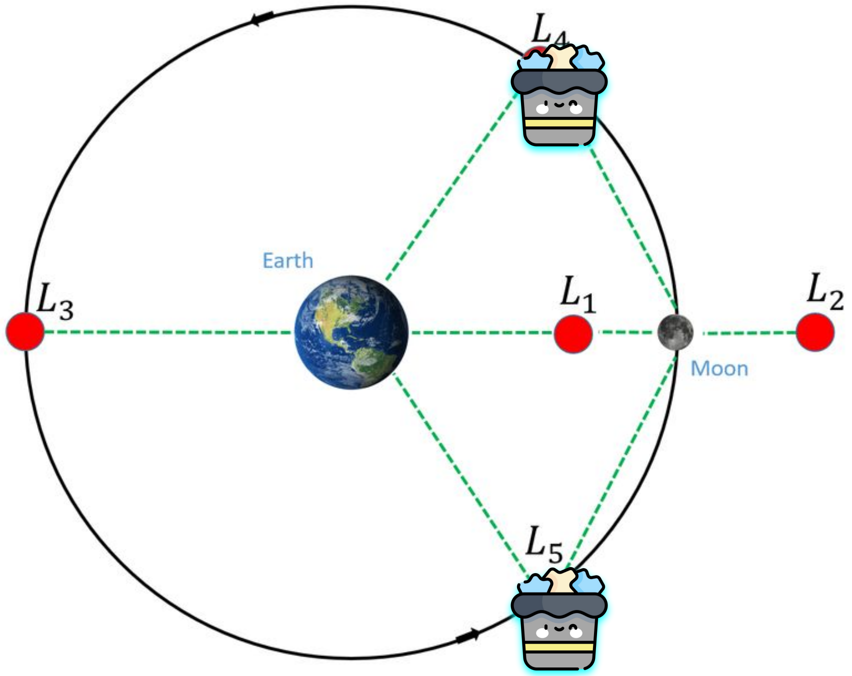
Starship

Difficulties / Challenges / Timeline
- Rendezvous is inherently risky due to collisions and creation of more debris
- This is expensive technology to create on a 1 debris for 1 reentry type of technology
- **Timeline**: Not immediately implementable but possible within 5 years timespan

Solution 3: Salvage Zone (*...Space Junkyard*)

*Active Debris Removal

- **Concept:** Establish debris collection zone at Earth-Moon L4/L5 or elsewhere
  - ADR spacecraft tow debris >10 cm
  - Objects remain stable, enabling future retrieval or repurpose
- **Why Lagrange Points:**
  - Naturally stable zones → no containment needed
  - Isolated from operational orbits
- **Technology:** ADR spacecraft w/ robotic arms or tentacles; Hall-effect thrusters (HETs) for controlled transfer
- **Advantages:**
  - Enables resource recovery and recycling
  - Reduces clutter in congested LEO/GEO
- **Risks/Timeline:** Potential collision buildup; Legal ambiguity over stored national/military debris; Need for long-term tracking and inventory control
- **Policy:** Market as "Salvage Zone" to promote positive framing; Needs international regulation and cooperation
- **Business Case:** Monetize salvage; Partner with in-space manufacturing firms



Solutions 2&3: Regulations, Policy Considerations

Technical Standards: NASA-STD-8719.14C

- Technological standards for capturing non-cooperative targets, list of previously validated technologies
  - Particularly relevant to re-entry heat shield design
- Compliance conventions regarding transportation & storage of potential ADR targets.
- Salvage zones at lagrange points 4 & 5 will need additional study to prove stability of storage plan, as lagrange points are not covered at all here.

Debris Passivation Standards: IADC 5.2.1

- Guidelines for rendering space objects inert before atmospheric entry to avoid explosive hazards.
- Requires removal of on-board volatile, flammable, explosive materials pre-repositioning/re-entry
  - This means batteries, propellant, power generation units, some measurement equipment types, etc
- TL;DR: applies to most ADR targets

Mission Planning & Orbital Debris Risk Assessment Requirements: IADC 5.4 & NPR-8715.6E

- Mandatory avoidance of in-orbit and post-mission collisions
- Requires trajectory contingency plans, orbital placement risk assessment, operational collision avoidance
- Requires submission of Orbital Debris Assessment Report(s) to assess potential risks of collision, re-entry hazards, environmental concerns, or long term effects.

Policy Gaps:

- Repurposing/salvage operations, lagrange point storage, economic risks associated with privatized ADR

Funding

The Funding Challenge

Key Challenge

- There is a dire need for financing options for addressing the debris that we have made and there is no realistic avenue for a ROI (Return on Investment) if an actor were to address the debris issue, and because of this we have developed the following options
- International collaboration on finances to address the existing and growing debris issue

Potential Options:

1. Tax/Fee based Scheme
   - This proposes a fee on a $ / kg of mass that reaches orbit with a mandate that launch providers take at max 50% of the costs before passing off the rest to satellite providers
2. Tradable Permit Scheme
   - Create a market-based system to cap allowable annual space activity, a permit system, and marketplace with international participants that powers market incentives for ADR
3. Increased FY25 Appropriation
   - Expand Office of Space Commerce funds by $14.6 million which would enhance debris research and development of robust Situational Awareness and Traffic Management capabilities

While none of these are complete “fixes,” all are potential options that would address significant areas of economic need for the development & deployment of ADR systems.

LAW + POLICY

Why Talk About The Legal Side of ADR?

- Space is getting really crowded and little is being done about it right now
- Law shapes what we *can* and *can't* do in space
- ADR raises legal issues around:
    - Sovereignty
    - Liability
    - Regulatory Oversight
    - National Security

Sovereignty

Global Communication & Coordination on Sovereignty & Ownership

- **The Problem: Deficiencies in Existing Laws**
  - Launching states retain indefinite ownership, hindering removal efforts
  - Lack of incentives and obligations for proactive debris mitigation and removal
  - No legal process (international side) to gain the ownership of debris or obtain approval for ADR

- **Proposed Solution:**
  - Establish an International Debris Clearance Authorization Mechanism under UNCOPUOS: Centralize cross-border ADR approvals and dispute resolution
  - Adopt a Presumptive Abandonment Principle to legally define debris abandonment rules based on the size

The Proposed "Presumptive Abandonment" Principle for Space Debris

Category	Specific Abandonment Criteria
Small Debris (< 10 cm)	Automatically abandoned at creation (or after 6 months) unless claimed; freely removable.
Medium Debris (10 cm – 1 m)	Presumed abandoned after 20 years of inactivity unless claimed; then removable.
Large Debris (1 m – 100 m)	Presumed abandoned after 20 years; removal allowed if no objection from launching state within 6 months of notification.
Very Large Debris (> 100 m)	Presumed abandoned after 20 years; removal requires 1-year notice and written consent from launching state.

Liability

Liability in Space Law

Liability in Space Law Today

- Liability governed by the Outer Space Treaty (1967) and Liability Convention (1972)
- Launching states are liable for damage caused by their space objects
- Fault-based standard applies to damage in space; strict liability for damage on Earth
- Liability follows the “launching state” — includes launching, procuring, or supervising entities

Gaps in the System

- No clear liability rules for abandoned or unregistered debris
- No guidance on third-party removal — risk of liability for good-faith ADR actors
- Difficult to determine "fault" in space collisions or failed removals

Obligations and Liabilities

Problems Due to Gaps in the System

- Uncertainty deters commercial investment in ADR technologies
- States may avoid ADR to avoid liability exposure

Proposed Solutions

- International "Safe Harbor" Regime
    a. Create legal protections for certified ADR missions targeting presumed-abandoned debris
    b. Incentivizes action while reducing legal risk
- Multilateral Debris Registry & Consent Mechanism
    a. Require states to register debris and periodically update ownership status.
    b. Facilitate automatic or conditional consent for removal of long-inactive objects

Regulatory Oversight

Clearing a Path—Key Questions & Solutions for ADR Regulation

Right Now - Fragmented U.S. Oversight

- No Single ADR Regulator: FAA (launch/reentry), FCC (spectrum), NOAA (remote sensing), and DOC all play roles—but no agency has full jurisdiction
- Office of Space Commerce (OSC): Could be a future lead, but lacks formal licensing authority today
- Regulatory Redundancy: Operators must seek multiple approvals, leading to inconsistent requirements and significant delays

Key Questions For Legislators

- How can we ensure licensing doesn't become a choke point?
- What can we do to reduce/remove regulatory redundancy
- How can we encourage innovation in the ADR space

The Regulatory Approval Bottleneck for ADR

Why this is a problem:

- ADR missions fall between the cracks – especially for in-orbit activity like rendezvous, capture, and deorbiting
- Lack of clarity discourages private sector investment and international cooperation

Proposed Solutions

- Designate the OSC as Lead ADR Regulator via legislation, consolidating fragmented authorities
- Create a Unified ADR Licensing Framework: FAA (launch), OSC (on-orbit activity), FCC (spectrum)—coordinated but not conflicting
- Clarify Roles in Space Policy Directives (SPD-3, SPD-6) to give agencies enforceable mandates, not just advisory roles

ADR and National Security

“Dual-Use” Nature of ADR Capabilities - Key Concerns

Dual-Use Challenges

- Civilian vs. Military Use: ADR (Active Debris Removal) technology can clean space debris or disable adversary satellites.
- Legal Ambiguity:
  - OST and PAROS prohibit militarization but lack clarity on dual-use technologies.
  - UN Charter allows force only in self-defense, creating legal gray areas.
- Security Risks:
  - ADR tech raises mistrust among nations, seen as potential anti-satellite (ASAT) weapons.
  - Escalates geopolitical tensions and risks arms races in space.

“Dual-Use” ADR technology is escalotory for international peace and national security under international and domestic legal regimes

"Dual-Use" Nature of ADR Capabilities - Impact and Solutions

Key Challenges

- Ambiguity: No clear distinction between civilian and military applications of ADR technologies
- Legal Gaps: OST and PAROS treaties lack specific provisions for dual-use systems
- Security Risks: ADR tech is perceived as potential anti-satellite weapons, escalating mistrust and tensions

Proposed Solutions

1. Define Acceptable Use: Establish international standards to distinguish civilian ADR technologies from militarized ones
2. Create Rules of Play: Develop transparent guidelines for deployment and operation under international law
3. Neutral Oversight: Form an independent body to monitor compliance and mediate disputes

Legal Reform is essential to create a clear definition between what ADR technologies are "dual-use", which are internationally/nationally acceptable, and "rules of play" on their use!

Legal Conclusions

The Goal:

A sustainable space environment for future generations

What’s Needed

- **Legal Reform:** Clear rules for ownership, liability, and ADR missions
- **Global Collaboration:** Unified standards and oversight to foster trust
- **Support Innovation:** Streamlined regulations to encourage private investment

Final Remarks

Final Remarks

We propose a three-tiered remediation framework:

1. Short-term: space-based laser system to remove small debris (1–10 cm)
2. Medium-term: "Pac-Man Method" to capture and return larger debris to Earth for reuse
3. Long-term: in-space salvage zone or "junkyard" to store recoverable materials

Funding:

- 2 different models: Domestic Tax/Fee, International Tradable Permit Scheme
- Suggested Increase in Office of Space Commerce Budget

Law & Policy: After providing essential ownership, liability, regulatory, and national security considerations for the engineering options, we recommend the following reforms:

1. Create international debris clearance system with size-based presumptive abandonment
2. Establish international liability sharing, waiver agreements, a removal fund, and PPPs
3. Let OSC lead ADR regulation, unify new ADR licensing, & empower relevant agencies
4. Define acceptable "dual-use" ADR technologies to establish acceptable "rules of play"

Let's clean up space together. Supporting long-term growth and utilization of the final frontier that has the potential to revolutionize human life back on Earth. **GO BLUE!**

Thank you!

Professor Donald Moore - MLaw
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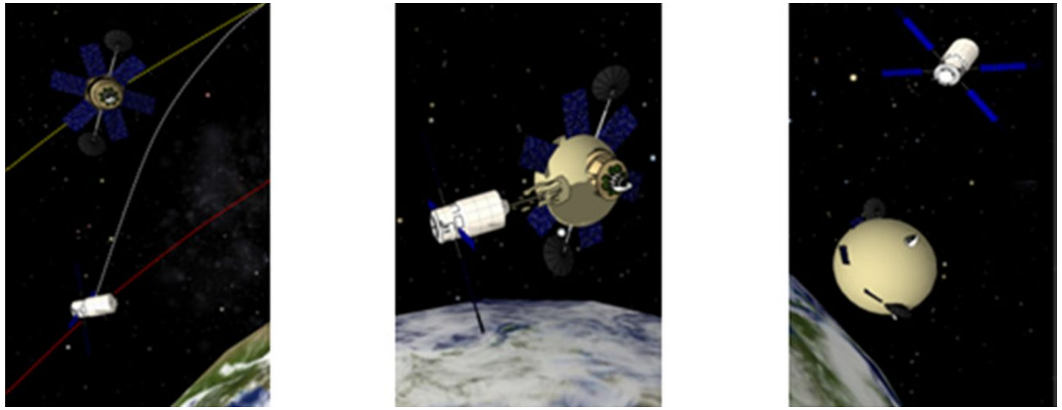
Nathan Simington - FCC Commissioner
Alexander Salter - Texas Tech Economics
Sarah Law - AstroScale Design & Operations
Mike Carrey - Elara Nova Space Consultancy
Blaire Kuplic - SpaceComm Chief of National Security
Therese Jones - NASA Office of Technology, Policy, & Strategy Senior Advisor

Backup Slides

Additional Considered Options for Capture/Removal

Foam

- Increases area to mass ratio through releasing foam at debris which forms a ball-like structure and causes atmospheric drag and speeds up the re-entry process
    - Atmospheric burnup of foam and debris
- Limited altitude due to passive re-entry



Example of foam based method
Source: ESA

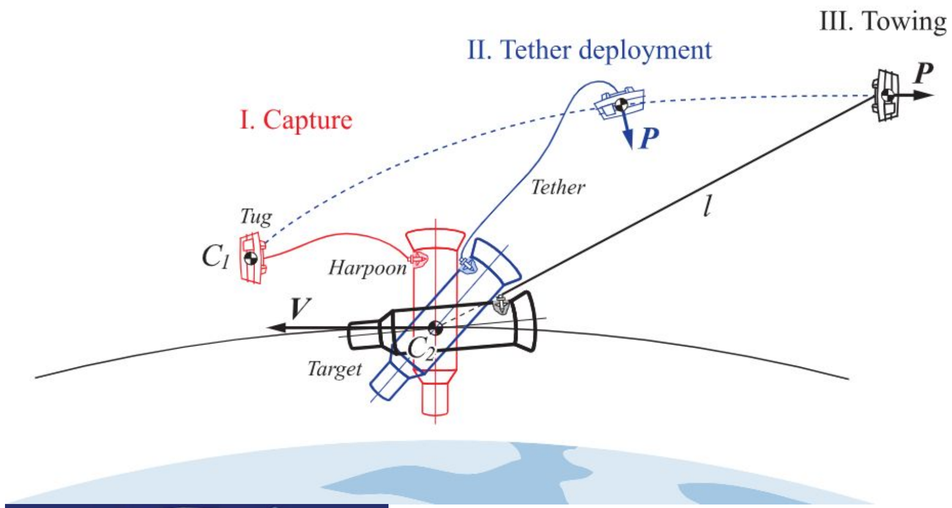
Additional Considered Options for Capture/Removal

Harpoon

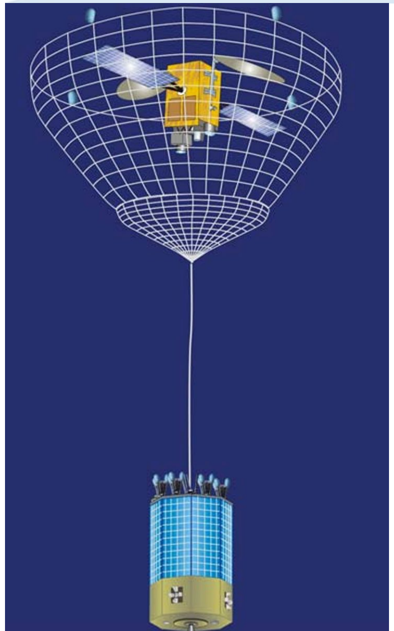
- Harpoon which is attached to a tether on a chaser spacecraft and launched at a target debris to penetrate it.
  - Risk of generating additional debris during capture.

Net

- Net attached to a tether on a chaser spacecraft with weights in the corners
  - Size dependent upon target debris
  - Risk of net entanglement if not properly aligned or launched



Example of harpoon capture system
Source: Sizov and Aslanov



Example of tether net capture system
Source: Kosuge and Kojima

Foundational Framework for Tackling Orbital Space Debris

Problem & Current Consensus:
Space debris demands international collaboration (legal/engineering consensus), but existing analyses lack actionable solutions.

Proposed Approach:
Target incremental progress by addressing manageable debris first, building systematic solutions through iterative technological development, policy alignment, and cross-border cooperation.

Methodology:
Analyse current constraints (physical, technical, legal) to prioritise low-risk, high-impact debris removal, fostering scalable technologies and adaptable frameworks.

Vision:
Gradual constraint relaxation as debris clearance advances, enabling holistic solutions across engineering, policy, and economics over time.

Notes on Collaboration Structuring

1. **Clearly defined boundaries:** the parties who have rights to earth orbit (i.e. to occupy an orbital slot) must be clearly defined, as must the boundaries of "earth's orbit" or, in Ostrom's terms, the common pool resource (CPR).
2. **Congruence between appropriation rules and local conditions:** rules regarding behavior in space are applied with respect to the actual capabilities of space actors themselves, the market that exists in orbital space, and legitimate concerns of fairness & equity of access.
3. **Collective-choice arrangements:** most individuals affected by the operational rules can participate in modifying the operational rules - ideally, this involves *all* actors, but is effective even when only a minority of actors participate in rule-adjustment mechanisms based in consensus in management of the CPR.
4. **Monitoring:** monitors who actively audit the orbital environment & behavior within it are either directly accountable to relevant space actors or are themselves the actors. This mostly implies the lack of a *need* for central planning in CPR management, only the existence of unified accountability.
5. **Graduated sanctions:** space actors who violate operational rules are *likely* to be assessed graduated sanctions depending on the seriousness and context of the offense) by other actors, by officials accountable to actors (if they exist), or by both. Again, emphasis on the lack of requirement for centralized standardization.
6. **Conflict-resolution mechanisms:** actors and their officials have rapid access to low-cost arenas to resolve conflicts among actors or between actors and officials (if they exist). These procedures do *not* need to be judged by an authority to be legitimate or effective; they are concerned only with the resolution of conflict. This is substantively different from the assessment of sanctions.
7. **Recognition of rights to organize:** the rights of actors to devise their own institutions are not challenged by external authorities. This is particularly advantageous to non-state actors, and means that all actors should not be regulated in how they organize, but only how they *behave* in the orbital environment.
8. **The "Nested enterprises" principle:** Rules regarding access to & behavior in space and the monitoring, enforcement, and modification of these rules should nest across enterprises relevant to space – not just the enterprises that *directly* access space. By diversifying the pool of actors that access space and the methods by which their behavior is monitored and (if necessary) sanctioned, the overall sustainability of the CPR is stabilized.

Debris Targeting: Risk Quantification

Effective ADR missions require effective debris object targeting

- Objects of "high risk" to the orbital environment should be prioritized for removal

An effective risk quantification tool can be built to assist in debris targeting, and should be open access, open source and oriented toward eventual standardization of orbital risk profiles

Risk quantification depends on multiple factors with subjective weights

- Different objects may be quantified with different risk values depending on what factors are/are not included
- Consequence (severity in case of collision) vs Probability (likelihood of collision) factors

Debris Targeting: Risk Quantification

Risk = consequence x probability

- Consequence: if a collision occurs with the object, how severe will it be?
- Probability: how likely is that the object will experience a collision?

Consequence factors:
- Debris mass
- Fragmentation potential
- Explosion potential
- Re-entry survivability
- Active satellites in the area

Probability factors:
- Debris size
- Density of the orbital area
- Average rates of collision in the area
- Previous near miss collisions
- Average debris lifetime in the area

Debris Targeting: Risk Quantification Tool

Debris targeting for ADR missions can be streamlined through a flexible risk quantification tool/software

- Allow users to customize risk calculations based off preferences
  - Risk calculations will be more reflective of user priorities/needs, increasing practical value
- Open-source approach leverages global expert knowledge
  - Accurate modeling/calculation of risk factors are active areas of research
- Equal access to citizens worldwide
  - Streamlining the process of selecting debris can help spur new ideas and demonstrate new technologies
- Single agreed upon source for risk quantification may assist in crafting a permit based economic market
  - Object risk values may be used as part of permit cost “reward” calculations for removing debris objects

Debris Tax: Funding Model to Tackle the Space Debris Problem

Funding Source

- Key Challenge related debris solutions is finding funding sources.
  - To create an economy out of the debris
  - Create a funding source for the issue
- The tax system we've developed ideally would be adapted globally

Basis of the Tax System

- This tax is proposed on a $ / kg of mass that reaches orbit.
  - We propose a mandate that launch providers take at least 50% of these costs before passing off the rest of the costs to the satellite providers
- All funding raised from this would be governed by a regulatory body that is represented by all agreeing member nations of the tax to avoid bias in investment decisions
  - Resources from this regulatory board will be directed toward companies developing technologies for active debris removal

Potential Risks

- Potential to hinder investments into industry as a whole or domestically
  - The advantage that the U.S. has with launch capabilities a small cost as demonstrated to the right should not hinder the American industry, and in fact would technologically give the U.S. the upper hand.
- Greater risk of getting funding too late, after a catastrophic event

Example of the System

- This is an isolated example of the system had it been implemented in 2024 for just SpaceX given their launch costs and launch operations

Falcon 9 2024 Launch Cost	$70,000,000
Kilograms to LEO	9500
Cost $/kg to orbit	$7,368
Disposal tax ($/kg)	$250
Total Launch Cost Increase	$2,375,000
Increase Cost to Launch Provider per/launch	$1,187,500
Increase Cost to Satellite Producer $/kg	$125
New Total $/kg for satellite manufacturers	$7,493
2024 SpaceX Total Disposal Tax Revenue	$ 320,600,000
2030 Total SpaceX Disposal Tax Revenue (if 20% launch increase year over year)	$960,000,000

Economic Governance Overview

This section is suggesting federal economic governance policy recommendations based on the FY25 request appropriation of $75.6 million for the Office of Space Commerce, significantly enhancing its operational and research capabilities. The requested appropriation would enable three critical initiatives:

- Expanded orbital debris material research
- Development of robust Space Situational Awareness (SSA) and Space Traffic Management (STM) capabilities
- Acquisition and retention of specialized professional staff for operational excellence

Orbital Debris Research Imperative & SSA Dev.

- Recent collaborative investments, such as the $550,000 grant from NASA and OSC for the "RAD Framework for the Moon" project at the University of Maryland, exemplify research initiatives requiring expansion under increased funding
- Robust STM capabilities serve three critical national interests:
  - National Defense (Countering adversarial satellite threats
  - Meteorological Forecasting(Proactive responses to transient space weather phenomena)
  - Technological Competitiveness(Furnishing advanced tracking equipment)

Legal Landscape

ADR technology is considered “dual-use,” meaning that it can be used for both civilian purposes, (removing space debris), and military purposes (disabling or removing an adversary's satellite). This places ADR missions at tension with regulators.

Outer Space Treaty (OST):

- Art. I Establishes space for “The benefit and interests of all countries” and Art. II prohibits national appropriation and the military use of space
- Art. IX of the OST obligates states to conduct space activities "with due regard to the corresponding interests of all other state signatories”
- Not legally binding though and no explicit recognition of “dual-use” capabilities of ADR.

UN Prevention of an Arms Race in Outer Space (PAROS):

- Aims to prevent space weaponization and ensure the peaceful use of space, which would reject ADR technologies that are “dual-use"
- Countries have veto power. The US has vetoed the PAROS Treaty effectively at the UN, opting instead to invest into efforts like Space Force.

UN Charter Articles on Use of Force:

- Prohibits force against other states, but the international law principle of *jus ad bellum* allows defensive force if debris threatens operations.
- Under *jus ad bellum*, defensive actions must meet necessity and proportionality.
- However, UN Security Council review also faces prospective veto from states active in space like the US, China, and Russia.

ASAT Testing Regulations:

- The UN General Assembly adopted a resolution to prevent Direct-Ascent ASAT testing, which the US followed with their own moratorium.
- Highlights a case of international recognition of restricting potential ASAT weapons for the sake of the orbital environment

UN Liability Convention + OST Art. VI:

- Launching states face absolute liability for damage which extends to private actors, creating national security risks from private ADR services.

US Department of Defense & Congress:

- Competing interests in space for commerce and national protection. Have recognized all ADR capabilities as being “dual-use.”