

Triumph of the Space Commons: Addressing the Impending Space Debris Crisis Without an International Treaty

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TRIUMPH OF THE SPACE COMMONS: ADDRESSING THE IMPENDING SPACE DEBRIS CRISIS WITHOUT AN INTERNATIONAL TREATY

JOSEPH KURT*

INTRODUCTION

Property damage resulting from floating flecks of paint generally would not rise to the top of anyone's list of environmental crises. And reasonably so. But what if those flecks are floating by at 17,500 miles per hour?¹ And what if there are millions of pieces of similarly swift flotsam, many thousands of which are much larger, heavier chunks of garbage?² Further, what if the property at risk of destruction had huge implications for weather forecasting, telecommunications, commerce, and national security?³ And finally, what if the problem were on track to get worse—much worse?⁴ Unfortunately, the above scenario is currently being played out in Earth's orbit, making the issue of ever-increasing space debris the greatest environmental crisis unknown to most people.⁵

The cognoscenti, however, understand well that the many thousands of pieces of man-made space debris orbiting the planet pose a grave threat to the wide range of human endeavors in space.⁶ There is

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¹ Sarah Laskow, *The Economics of Space Junk*, BOS. GLOBE (Oct. 13, 2013), <http://www.bostonglobe.com/ideas/2013/10/12/the-economics-space-junk/ARGKnCkIKMnzGyi63HpPHM/story.html> [<http://perma.cc/V7K9-USCT>].

² Mary Button, Note, *Cleaning Up Space: The Madrid Protocol to the Antarctic Treaty as a Model for Regulating Orbital Debris*, 37 WM. & MARY ENVTL. L. & POL'Y REV. 539 (2013).

³ Scott J. Shackelford, *Governing the Final Frontier: A Polycentric Approach to Managing Space Weaponization and Debris*, 51 AM. BUS. L.J. 429, 430–32 (2014).

⁴ Laskow, *supra* note 1.

⁵ *Id.*

⁶ See generally Joseph S. Imburgia, *Space Debris and Its Threat to National Security: A Proposal for a Binding International Agreement to Clean Up the Junk*, 44 VAND. J. TRANSNAT'L

also a broad consensus that the space debris problem necessitates a timely international response.⁷ And if one peruses scholarly output on the subject, one might also assume that only a comprehensive and binding regulatory regime, in the form of an international treaty, can adequately deal with this impending crisis.⁸ Calls for such regulation are grounded (explicitly or implicitly) on the assumption that the common ownership of space by all nations is leading us towards a classic “tragedy of the commons,” whereby a group of actors’ shortsightedness leads them to overuse a shared resource to the point of ruining the resource for all.⁹

But despite the stream of proposals for some type of international regulatory regime to address the issue, no measurable progress has been made towards this end.¹⁰

This Note argues that the problem caused by proliferating orbital debris can be effectively addressed without a comprehensive treaty. Part I describes the growing crisis posed by space debris generally and also explains why this crisis has the appearance of a tragedy of the commons in the making. Part II describes the shortcomings of the current legal regime governing space and suggests that, while the development of a new legal regime is perhaps ideal, a treaty along these lines is unlikely to materialize any time soon. Part III avers that an objective analysis suggests that, even in the absence of a comprehensive treaty, spacefaring nations are likely to avoid a tragedy of the commons. This analysis identifies underlying forces at play that provide incentives for spacefaring nations to cooperate, describes promising technological developments that will ameliorate the problem, and applies game theory as well as scholarship analyzing the development of informal norms to the problem of orbital debris. Finally, Part IV will suggest steps policy makers can take to ensure that a tragedy of the commons in space is avoided.

L. 589 (2011).

⁷ *Global Experts Agree Action Needed on Space Debris*, EUR. SPACE AGENCY (Apr. 25, 2013), http://www.esa.int/Our_Activities/Operations/Space_Debris/Global_experts_agree_action_needed_on_space_debris [<http://perma.cc/F4MJ-2W67>].

⁸ Imburgia, *supra* note 6; Edgar M. Hollandsworth, *THE SPACE DEBRIS CRISIS: TIME FOR AN INTERNATIONAL TREATY* 17 (Mar. 23, 2011) (unpublished strategy research project, U.S. Army War College).

⁹ Brian Bremner & Peter Robison, *Cleaning Up the Final Frontier*, BLOOMBERG (Jan. 16, 2014), <http://www.businessweek.com/articles/2014-01-16/space-junk-in-earth-orbit-the-cleanup-problem> [<http://perma.cc/8U77-7MAB>].

¹⁰ Hollandsworth, *supra* note 8, at 17 (calling for a comprehensive treaty but acknowledging that one is “beyond the near-term horizon”).

I. THE HAZARD OF SPACE DEBRIS

A. *Defining and Quantifying Space Debris*

As it is generally defined, space debris is a blanket term for the remaining refuse of the more than 7,000 man-made objects launched into orbit since the dawn of the space age.¹¹ Space debris includes defunct satellites, discharged rocket components, loose nuts and bolts, space tools lost by astronauts, and even flecks of paint from spacecraft.¹² In other words, space debris includes every individual man-made scrap of material in space that is not a functioning object.¹³ Some of this material falls out of orbit within months or years, either falling back to Earth or burning up in the atmosphere.¹⁴ However, the vast majority of space debris will remain in orbit for decades or even centuries.¹⁵

All told, there are more than half a million items of space debris in lower earth orbit (“LEO”) and geosynchronous orbit (“GEO”), the two orbital zones where humankind carries out almost all of its space activities.¹⁶ About 16,000 of these objects are larger than ten centimeters in diameter, including nonfunctioning satellites.¹⁷ When objects of this size collide with a functioning satellite, the likely result is the complete destruction of the craft.¹⁸ The vast majority of objects in this class are relatively small, yet are still highly destructive because of their incredible velocity.¹⁹ In addition to countless items smaller than one centimeter in diameter, which can still cause significant damage to satellites and spacecraft, there are approximately 400,000 pieces of debris between one and ten centimeters in diameter.²⁰ These latter objects can cause severe damage to space vehicles, even completely destroying them.²¹

¹¹ See Bremner & Robison, *supra* note 9.

¹² Krista Fuentes, Kathy Jones & David Wright, *A Minefield in Earth Orbit: How Space Debris is Spinning Out of Control*, SCI. AM. (Feb. 1, 2012), <http://www.scientificamerican.com/article/how-space-debris-spinning-out-of-control/> [<http://perma.cc/H23K-HER9>].

¹³ Imburgia, *supra* note 6, at 593–94.

¹⁴ Robert C. Bird, *Procedural Challenges to Environmental Regulation of Space Debris*, 40 AM. BUS. L.J. 635, 637 (2003).

¹⁵ Luke Punnakanta, Note, *Space Torts: Applying Nuisance and Negligence to Orbital Debris*, 86 S. CAL. L. REV. 163, 166 (2012).

¹⁶ Bird, *supra* note 14, at n.25. While the gravity of the space debris crisis differs between LEO and GEO, this Note will largely forego distinguishing between the two. This Note’s general economic analysis of the space debris problem is applicable to both orbital zones.

¹⁷ Fuentes, *supra* note 12.

¹⁸ *Id.*

¹⁹ *Id.*

²⁰ *Id.*

²¹ *Id.*

B. *The Costs Incurred by Space Debris*

In 2012, the International Space Station (“ISS”) performed a trajectory-changing engine-burn to avoid a small piece of debris.²² Such a maneuver is costly,²³ but necessary to avoid the kind of devastating puncture that even a very small piece of debris can create.²⁴ The increasing frequency of such maneuvers is just one of the economic costs of the space debris problem in its present state.²⁵ For example, the initial launches of numerous spacecraft have been delayed because of the presence of space debris in the planned flight paths.²⁶

Another cost incurred by the vast quantity of space debris in orbit is adding protective shields to satellites that can minimize the damage from very small pieces of debris.²⁷ Not only is such a shield expensive in its own right, it adds weight to the satellite and thus increases the amount of fuel required—a cost increase that is born over the lifetime of the craft.²⁸

As the amount of debris in space grows, the preventive measures required to conduct activities in space will greatly increase the cost of such operations.²⁹ Of course, the price of replacing a satellite that is completely destroyed is the most expensive damage space debris can cause to a particular craft, with a potential price tag in the hundreds of millions of dollars.³⁰ Over the long term, however, a much higher price will be borne by all parties who have a stake in a usable orbit.

²² *Space Station Dodges Super-fast Debris*, UPI (Jan. 13, 2012), http://www.upi.com/Science_News/2012/01/13/Space-station-dodges-super-fast-debris/UPI-40381326448800/?spt=hs&or=sn [<http://perma.cc/NP8F-8LAP>].

²³ Press Release, European Commission, *Avoiding Damage From Space Debris—Space Surveillance and Tracking Proposal* (Feb. 28, 2013), http://europa.eu/rapid/press-release_MEMO-13-149_en.htm [<http://perma.cc/N4Q8-M63V>] [hereinafter *Press Release*].

²⁴ *Space Station Dodges Super-fast Debris*, *supra* note 22.

²⁵ Press Release, *supra* note 23.

²⁶ Imburgia, *supra* note 6, at 595.

²⁷ Meghan R. Plantz, *Orbital Debris: Out of Space*, 40 GA. J. INT'L & COMP. L. 585, 598 (2012).

²⁸ *NASA Team Proposes to Use Laser to Track Orbital Debris* (Oct. 27, 2014), <http://www.nasa.gov/content/goddard/nasa-team-proposes-to-use-laser-to-track-orbital-debris/#.VHCloqVi6II> [<http://perma.cc/PA43-VESQ>] [hereinafter *NASA Team Proposes*].

²⁹ Kate Kelland, *The High Price of Avoiding Space Junk*, Nov. 10, 2009, WASH. POST, available at <http://www.washingtonpost.com/wp-dyn/content/article/2009/11/06/AR2009110603555.html> [<http://perma.cc/3VS4-SCLV>].

³⁰ Jared B. Taylor, *Tragedy of the Space Commons: A Market Mechanism Solution to the Space Debris Problem*, 50 COLUM. J. TRANSNAT'L L. 253, 262 (2011).

C. *A Growing Problem: Satellite Collisions and the Kessler Syndrome*

Despite the high costs imposed by the large amounts of space debris already in orbit, this problem might not rise to the level of a *crisis* were the rate of space debris creation holding steadily. Unfortunately, the amount of space debris orbiting the Earth is increasing at ever-faster rates.³¹ Two relatively recent events bear the brunt of the blame.³²

In 2007, China used an anti-satellite missile to destroy one of its own weather satellites.³³ That collision alone added over two thousand bits of trackable debris to Earth's orbit, and tens of thousands of smaller bits of debris.³⁴ Another devastating collision occurred in 2009 when an active, privately owned satellite crossed paths with a defunct Russian satellite.³⁵ These two events alone are responsible for over a third of all debris in Earth's orbit.³⁶

By creating innumerable new pieces of space debris, collisions such as these in turn make further collisions more likely.³⁷ The Kessler Syndrome is the term given to this exponential growth in the amount of space debris that would be the inevitable byproduct of a cascade of ever more frequent collisions of space objects.³⁸ The end result of the Kessler Syndrome is catastrophe: the orbital zones surrounding the Earth would be rendered unusable.³⁹ At some point, a cascade of collisions will gather enough momentum as to make this phenomenon irreversible.⁴⁰ Scientists cannot know how imminent such a tipping point is, but some believe it could arrive within a decade or so if the problem is not mitigated.⁴¹

³¹ Fuentes, *supra* note 12.

³² Button, *supra* note 2, at 546.

³³ Kelland, *supra* note 29.

³⁴ Button, *supra* note 2, at 546.

³⁵ *Id.*

³⁶ Kelland, *supra* note 29.

³⁷ Corrine Burns, *Space junk apocalypse: just like Gravity?*, THE GUARDIAN SCI. BLOG (Nov. 15, 2013), <http://www.theguardian.com/science/blog/2013/nov/15/space-junk-apocalypse-gravity> [<http://perma.cc/G6HW-CTWC>].

³⁸ Brad Plumer, *Space trash is a big problem. These economists have a solution*, WASH. POST WONKBLOG (Oct. 24, 2013), <http://www.washingtonpost.com/blogs/wonkblog/wp/2013/10/24/space-is-filling-up-with-garbage-heres-why-we-should-tax-it/> [<http://perma.cc/3F7V-8UMZ>].

³⁹ *Id.*

⁴⁰ *Id.*

⁴¹ *Id.*

D. *Space Debris: The Prototypical Tragedy of the Commons?*

Many analysts suggest that the polluting of Earth's orbital space, potentially to a point of rendering it unusable, is a quintessential "tragedy of the commons."⁴² It is easy to see why. A tragedy of the commons occurs when actors overuse a commonly shared resource.⁴³ Garret Hardin's classic example of farmers grazing cattle in a public pasture illustrates the propensity of actors to make self-interested decisions about resource allocation that ultimately destroy the common resource for all.⁴⁴ This result occurs because, paradoxically, actors make collectively foolish choices by acting rationally in a series of instances.⁴⁵

Take the example of the aforementioned farmers, who must repeatedly decide whether to bring one more cattle to graze in the public pasture. In each of these instances, the nature of a cost-benefit analysis with respect to a commonly owned resource will lead her to conclude that she should introduce the additional animal.⁴⁶ The reason is that the individual farmer bears only a small *fraction of the cost* of adding one more animal because that cost (less usable pasture) is divided equally among all who use the pasture.⁴⁷ And, conversely, the same farmer receives *all of the benefit* (one more well-fed cow).⁴⁸

To frame the situation mathematically, an individual farmer's share of the cost can be quantified as the following fraction: "one" over the number of farmers using the pasture (i.e., "one-tenth" if she is one of ten farmers).⁴⁹ The farmer, however, will receive a full unit of benefit—i.e., "one."⁵⁰ Thus, the farmer's calculation consists of weighing *one* (her benefit) against, say, *one-tenth* (her cost, which in any case will be some fraction less than one).⁵¹ Clearly, the instant cost-benefit analysis suggests that she should bring one more cattle to pasture.⁵²

⁴² Bremner & Robison, *supra* note 9.

⁴³ Lee Anne Fennell, *Common Interest Tragedies*, 98 NW. U. L. REV. 907, 914 (2004) (explaining that tragedies of the commons occur when necessary care of common resources is not undertaken).

⁴⁴ *Id.*

⁴⁵ Bremner & Robison, *supra* note 9.

⁴⁶ Fennell, *supra* note 43, at 914.

⁴⁷ *Id.*

⁴⁸ *Id.*

⁴⁹ *Cf. id.*

⁵⁰ *Cf. id.*

⁵¹ *Cf. id.*

⁵² *Cf. Fennell, supra* note 43, at 914.

And to translate this phenomenon into formal economic terms, actors sharing a common pool resource have a tendency to overuse the shared resource because they internalize all of the gain of their own additional use while they externalize most of the cost of that same use.⁵³ They will continue to make such “rational” calculations until they arrive at a tragic result: the finite resource they shared will be depleted until it is no longer available to any of them.⁵⁴

E. Space: The Greatest Commons

International space law unambiguously establishes outer space as a universal commons.⁵⁵ The Outer Space Treaty of 1967 (“OST”) declares that space must be “free for exploration and use by all States” and further prohibits the appropriation of space or celestial bodies by any single nation.⁵⁶ Subsequent treaties have further enshrined the principal of space as a common resource owned by all of humankind.⁵⁷

The upshot of this otherwise noble idea, however, is that space takes on the character of Hardin’s cattle pasture: free access to space makes it ripe for overuse.⁵⁸ The vastness of space would make such overuse unlikely were only spacecraft and satellites at issue, but ever-growing amounts of space debris could render space as unusable as the overgrazed pasture. Actors in space are faced with the same calculation as Hardin’s farmer: the cost of their adding more debris to space is spread amongst all users, but each actor reaps the full benefit of the use of space that results in the creation of more orbital debris.

II. THE NEGLIGIBLE ROLE OF INTERNATIONAL SPACE LAW,
PAST AND FUTURE

A. *Overview of Current Space Law*

Five widely adopted UN Treaties comprise the current legal regime regarding outer space. OST is the foundation of all space law and was

⁵³ *Id.*

⁵⁴ *See id.*

⁵⁵ Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies, Jan. 27, 1967, 610 U.N.T.S. 205 [hereinafter OST], available at <http://www.unoosa.org/pdf/publications/STSPACE11E.pdf> [<http://perma.cc/Z7VN-TSNF>].

⁵⁶ *Id.*

⁵⁷ Taylor, *supra* note 30, at 259–60.

⁵⁸ *Id.* at 245–55.

followed by separate agreements treating the rescue of astronauts, liability for damage caused by space objects, the registration of objects in space, and activities on the moon.⁵⁹

Unfortunately, there is widespread agreement that these treaties are wholly inadequate to handle the space debris crisis.⁶⁰ For one thing, these treaties make no mention of “space debris,” only “space objects.”⁶¹ It is not at all clear whether the latter term encompasses the former.⁶² And though the OST prohibits the “harmful contamination” of space, this term’s definition is similarly murky.⁶³ The Convention on International Liability for Damage Caused by Space Objects (“Liability Convention”) might seem to disincentivise the creation of damage-causing debris.⁶⁴ However, the uncertainty over whether “space debris” is covered by the treaty, coupled with the difficulty of proving fault for the purpose of attaching liability, renders the Liability Convention unlikely to alter the behaviors of the actors at issue.⁶⁵

In 2007, the United Nations General Assembly endorsed the Space Debris Mitigation Guidelines (“Mitigation Guidelines”) of the Committee on Peaceful Uses of Outer Space (“COPUOS”).⁶⁶ These guidelines are certainly valuable as a set of “best practices,” but they are completely voluntary and not enforceable.⁶⁷ While NASA and the European Space Agency have adopted the Mitigation Guidelines, China’s 2007 ASAT test was a blatant violation of similarly voluntary protocols already in place.⁶⁸ The spacefaring community needs greater reassurance that all actors will comply with these protocols.

B. Calls for a Comprehensive Treaty to Address the Problem of Space Debris

Scientists have long been concerned about the issue of space debris, with COPUOS having begun to address the issue of space debris as far

⁵⁹ Shackelford, *supra* note 3, at 448–49.

⁶⁰ See generally Imburgia, *supra* note 6, at 593; Button, *supra* note 2.

⁶¹ Imburgia, *supra* note 6, at 615.

⁶² *Id.*

⁶³ *Id.* at 614–15.

⁶⁴ *Id.* at 617–18.

⁶⁵ *Id.*

⁶⁶ United Nations Office for Outer Space Affairs, *Space Debris Mitigation Guidelines of the Committee on Peaceful Uses of Outer Space* (2010) [hereinafter *Mitigation Guidelines*], available at http://orbitaldebris.jsc.nasa.gov/library/Space%20Debris%20Mitigation%20Guidelines_COPUOS.pdf [<http://perma.cc/NL4U-DK9S>].

⁶⁷ Hollandsworth, *supra* note 8, at 18.

⁶⁸ *Id.*

back as 1993.⁶⁹ And for more than two decades, commentators have been calling for some type of centralized regime to deal with the growing problem of orbital debris.⁷⁰ Some proposals are framed as market-based approaches, but contain numerous mandatory elements, thus requiring a treaty to be universally enforceable.⁷¹

One common proposal is for a tax on space launches.⁷² The increase in cost would deter some actors from adding more objects to the Earth's orbit, while the revenues collected would fund efforts to clean up space.⁷³ There is no authority to impose such a tax, however, until nations grant it through a treaty.⁷⁴ Another creative approach suggests various avenues by which tort law could be applied to the problem of space debris, curing the defects of the Liability Convention.⁷⁵

Other analysts expressly call for a comprehensive treaty, usually suggesting a host of measures that should be included.⁷⁶ One commentator posits the idea that the Protocol on Environmental Protection to the Antarctic Treaty can serve as a model.⁷⁷ Whether a treaty is explicitly called for, or whether analysts focus on one particular mechanism (i.e., liability rules), the essence of all of these proposals is that they are binding, enforceable, and near universal.⁷⁸ The idea that voluntary cooperation is sufficient is generally dismissed.⁷⁹

C. *A Comprehensive Treaty in the Near Term Is Unlikely*

The most recent convention dealing with activities in outer space, the Agreement Governing the Activities of States on the Moon and Other Celestial Bodies, was drafted in 1979.⁸⁰ There has been no follow-up

⁶⁹ Imburgia, *supra* note 6, at 620.

⁷⁰ See generally Lawrence D. Roberts, *Addressing the Problem of Orbital Debris: Combining International Regulatory and Liability Regimes*, 15 B.C. INT'L & COMP. L. REV. 51 (Dec. 1, 1992).

⁷¹ *Id.* at 68–70.

⁷² Plumer, *supra* note 38.

⁷³ *Id.*

⁷⁴ *Id.*

⁷⁵ See generally Punnakanta, *supra* note 15.

⁷⁶ See generally Imburgia, *supra* note 6, at 593; Hollandsworth, *supra* note 8.

⁷⁷ See generally Button, *supra* note 2.

⁷⁸ For many of these proposals, this binding and universal nature is necessarily implied.

⁷⁹ Thierry Senechal, *Orbital Debris: Drafting, Negotiating, Implementing a Convention* 62–63 (June 2007) (unpublished M.B.A. Thesis, M.I.T. Sloan School of Management), available at <http://web.mit.edu/stgs/pdfs/Orbital%20Debris%20Convention%20Thierry%20Senechal%2011%20May%202007.pdf> [<http://perma.cc/JTK9-N5YP>].

⁸⁰ *Id.* at 55.

convention in three and a half decades, despite the existence of many important and unresolved issues regarding the use of space.⁸¹ Many treaty advocates have themselves adeptly described the substantial obstacles that likely explain this lack of action.⁸²

Some of the difficulties apply generally to forming international conventions and include procedural issues such as which parties will draft the treaty, methods of implementation, and monitoring and compliance measures.⁸³ Determining the scope of the issues to be covered poses particularly thorny questions in the context of orbital debris.⁸⁴ Will the treaty merely prescribe mitigation protocols?⁸⁵ Or will it also impose liability rules?⁸⁶ Broadening the scope of issues may provide for a more complete redress of the problem, but also implicates national security concerns, the ability of space programs to operate effectively, and barriers to entry by nations hoping to become active in space.⁸⁷

Perhaps, in theory, these obstacles can be overcome. But interestingly, even advocates of a comprehensive treaty seem to acknowledge that efforts towards achieving such a pact are, for the foreseeable future, moribund.⁸⁸

III. REASONS FOR HOPE: WHY INTERNATIONAL ACTORS WILL AVOID A TRAGEDY OF THE SPACE COMMONS WITHOUT A COMPREHENSIVE TREATY

A binding international regime—i.e., a comprehensive treaty—governing space debris might well be the most prudent international response to the issue.⁸⁹ But for all the reasons discussed above, anything approaching a comprehensive agreement is nowhere in sight.⁹⁰ If the need

⁸¹ Shackelford, *supra* note 3, at 500–01.

⁸² See Senechal, *supra* note 79, at 56–58.

⁸³ *Id.* at 56.

⁸⁴ *Id.* at 57.

⁸⁵ *Id.*

⁸⁶ *Id.*

⁸⁷ Hollandsworth, *supra* note 8, at 22–23. This essay touches lightly on the concerns of nations with nascent space programs who have not contributed to the space debris problem at all, and who are unlikely to agree to be bound by the same rules as China, Russia, and the U.S., who have almost exclusively caused the problem.

⁸⁸ *Id.* at 17.

⁸⁹ See generally Imburgia, *supra* note 6.

⁹⁰ Plumer, *supra* note 38.

for such a regime is as dire as many commentators suggest,⁹¹ perhaps panic is in order.

However, this Part argues that in addition to the significant obstacles to achieving a comprehensive treaty to deal with space debris, there is perhaps an even more compelling reason why there has been almost no progress in this direction: the space debris problem can be effectively addressed without a binding treaty.

This claim flies in the face of common underlying assumptions about solving tragedies of the commons.⁹² Nevertheless, Part III of this Note will examine the space debris problem through three (overlapping) lenses that each suggest that nations with interests in space will cooperate to avoid a catastrophe in Earth's orbit. Section A will demonstrate that realistic solutions to the problem are entirely feasible—and on the horizon. Section B, using the issue of global climate change as a point of comparison, will argue that political cooperation can be achieved without the force of international law. And Section C, informed by the practical and political considerations of the first two sections, will apply economic theories that also suggest that future international cooperation is highly likely to resolve the issue of space debris.

A. *Practical Considerations: Feasible Solutions to the Space Debris Problem Are on Their Way*

One key question in assessing whether an international treaty is a requisite for solving the space debris problem is just how difficult it will be to fashion a remedy. The more complex and costly are feasible solutions, the more likely it is that a comprehensive regime is necessary to bind the various actors together.⁹³

A good place to begin is to determine just how imminent is the onset of the cascade of exponentially more frequent debris-creating collisions, known as the Kessler Syndrome.⁹⁴ To be certain, no one can be sure—this phenomenon being subject to highly complex probabilities.⁹⁵ Indeed, experts' estimates of when such a cascade will become irreversible vary

⁹¹ See generally Imburgia, *supra* note 6.

⁹² Katherine Trisolini, *All Hands on Deck: Local Governments and the Potential for Bidirectional Climate Change Regulation*, 62 STAN. L. REV. 669, 681 (2010).

⁹³ See *infra* Part III.C.

⁹⁴ Burns, *supra* note 37.

⁹⁵ *Id.* Donald Kessler's original insight about space debris stemmed from his application of algorithms he had earlier performed regarding meteorite collisions. *Id.*

widely.⁹⁶ The National Research Council produced a report in 2011 that suggested that “space might be just 10 or 20 years away from severe problems.”⁹⁷ In fact, the cascading effect has already begun, albeit at a modest pace.⁹⁸ However, Donald Kessler, who first described the eponymous effect in 1978, has significantly recalibrated his own outlook over the years.⁹⁹ Originally, Kessler predicted that catastrophe would result by the year 2000.¹⁰⁰ That date long passed, Kessler now speaks of a century-long process that “we have time to deal with.”¹⁰¹

Nevertheless, few would disagree with Christophe Bonnal of the Centre National d'Études Spatiales (“CNES”), the French space agency, who says that it is “not yet clear” how much time we have to act.¹⁰² None of this is to say that interested parties should not act with great dispatch to address the space debris problem. Even if catastrophe is not on the immediate horizon—as some have suggested—Heiner Klinkrad, the European Space Agency's leading authority on space debris points out that “[t]he longer you wait, the more difficult and far more expensive” any solution will be.¹⁰³

The additional slack in plausible timelines is cause for optimism when one considers the progress being made towards remediating the problem of space debris. Such remediation entails a three-pronged approach: preventive measures to reduce the creation of new debris,¹⁰⁴ space debris tracking technologies,¹⁰⁵ and active debris removal (“ADR”).¹⁰⁶

In an effort to address the first prong, the United Nations General Assembly in 2007 endorsed the COPUOS Space Debris Mitigation Guidelines.¹⁰⁷ The recommended measures include design changes which would

⁹⁶ Jonathan Amos, ‘Urgent Need’ to Remove Space Debris, BBC NEWS (Apr. 25, 2013), <http://www.bbc.com/news/science-environment-22299403?print=true> [<http://perma.cc/Z6FF-CVCC>]; Maria Sheahan, *Space Junk Needs to be Removed from Earth's Orbit, Says ESA*, REUTERS (Apr. 25, 2013) <http://www.thesudburystar.com/2013/04/25/space-junk-needs-to-be-removed-from-earths-orbit-says-esa> [<http://perma.cc/2CSZ-GYMC>].

⁹⁷ Plumer, *supra* note 38.

⁹⁸ Burns, *supra* note 37.

⁹⁹ *Id.*

¹⁰⁰ Plumer, *supra* note 38.

¹⁰¹ Burns, *supra* note 37.

¹⁰² Amos, *supra* note 96.

¹⁰³ Sheahan, *supra* note 96.

¹⁰⁴ See generally *Mitigation Guidelines*, *supra* note 66.

¹⁰⁵ *NASA Team Proposes*, *supra* note 28.

¹⁰⁶ *Orbital Debris Remediation*, NASA, <http://orbitaldebris.jsc.nasa.gov/Remediation/remediation.html> [<http://perma.cc/T4UT-688P>].

¹⁰⁷ *Mitigation Guidelines*, *supra* note 66.

avoid the previously common practice of releasing debris during standard operations, refraining from intentional destruction of space objects, and limiting the risk of collisions through avoidance maneuvers and delaying launch times.¹⁰⁸ As the COPUOS document points out, many of these practices had already been adopted by spacefaring nations.¹⁰⁹

Compliance with the COPUOS Mitigation Guidelines is voluntary and has not been universal,¹¹⁰ however, many nations do take steps beyond those called for in the Mitigation Guidelines, recognizing the importance of redressing the issue.¹¹¹ That said, even if no nation ever again launched a single object into outer space, the operation of the Kessler Syndrome would ensure that, over time, continuing collisions amongst already present objects would result in Earth's orbit being rendered unusable.¹¹²

Improvements in space debris tracking technology are another partial solution that promises to help actors avoid collisions by identifying orbital debris in the path of satellites or spacecraft.¹¹³ There are limits on the effectiveness of such tracking, however, including the inability of some optical systems to track objects at night.¹¹⁴ Moreover, commonly employed systems cannot continually track objects smaller than thirty centimeters in diameter.¹¹⁵ New systems are being developed, however, that will use lasers that can track the location of objects as small as a softball—sometimes to within one meter.¹¹⁶ Such technology is still at the planning stage for NASA,¹¹⁷ but Lockheed Martin is teaming up with an Australian-based company on a laser-tracking project already in the works.¹¹⁸ Another promising development comes from scientists at the Massachusetts Institute of Technology, who are working on soccer-ball-sized robots

¹⁰⁸ See generally *id.*

¹⁰⁹ *Id.* at iv.

¹¹⁰ Hollandsworth, *supra* note 8, at 18.

¹¹¹ Zhao Lei, *China aids in cutting down space debris*, CHINADAILY EUR. ED. (May 13, 2014).

¹¹² *Orbital Debris Remediation*, *supra* note 106.

¹¹³ *Electro Optic Systems Holdings Limited (ASX:EOS) To Build The First Automated Space Debris Tracker In The World*, ABN NEWSWIRE (July 10, 2010), http://www.abnnews.wire.net/press/en/63337/Electro_Optic_Systems_Holds_Limited_To_Build_The_First_Automated_Space_Debris_Tracker_In_The_World.html [<http://perma.cc/33EN-FACN>].

¹¹⁴ *NASA Team Proposes*, *supra* note 28.

¹¹⁵ Fuentes, *supra* note 12.

¹¹⁶ *NASA Team Proposes*, *supra* note 28.

¹¹⁷ *Id.*

¹¹⁸ Ben Geier, *Lockheed Martin Wants to Be a Space Janitor*, FORTUNE (Aug. 26, 2014), <http://fortune.com/2014/08/26/lockheed-martin-wants-to-be-a-space-janitor/> [<http://perma.cc/AR6H-324U>].

designed to travel alongside the ISS, investigating potentially harmful space debris along the way.¹¹⁹

But while tracking space debris can help avoid specific accidents, and thus slow the machinations of the Kessler Syndrome, only ADR can stabilize the space environment.¹²⁰

Fortunately, the targets for ADR that scientists believe will allow us to forestall an irreversible cascade of collisions are relatively modest.¹²¹ The most common estimate is that removing five to ten large pieces of debris per year is enough to keep the Kessler Syndrome at bay.¹²² And even more encouraging is that a broad array of national and private actors are exploring a plethora of ADR methods.¹²³ For example, the Japanese hope to deploy, by 2019, a magnetic net that will draw pieces of space debris down to the Earth's atmosphere, where they will burn up.¹²⁴ Such use of the atmosphere to incinerate debris is a common element of many ADR strategies, whether they employ nets, harpoons, tentacles, or ion thrusters to impact the debris.¹²⁵ Meanwhile, a German Space Agency program is developing the means to robotically capture satellites.¹²⁶ Other solutions include using enormous puffs of air, static electricity, or lasers to throw objects out of orbit.¹²⁷

Obviously, such projects carry a hefty price tag, but funding is coming in from a variety of sources.¹²⁸ A laser-based project being developed by Australian National University, for example, received \$20 million from the Australian government and an additional \$130 million from NASA and other international public and private actors.¹²⁹ But even these sums

¹¹⁹ Paul Marks, 'Soccer-ball' robots to patrol space for deadly junk, *NEW SCIENTIST* (Sept. 3, 2014), available at <http://www.newscientist.com/article/mg22329854-300-soccer-ball-robots-to-patrol-space-for-deadly-junk/> [<http://perma.cc/CL66-K5K6>].

¹²⁰ Leonard David, 'Sling-Sat' Space Junk System Promises Low-Cost Removal Of Orbital Debris, *HUFFINGTON POST* (Mar. 4, 2013), http://www.huffingtonpost.com/2013/03/04/sling-sat-space-junk-orbital-debris_n_2805127.html [<http://perma.cc/RWU2-XEAS>].

¹²¹ Sheahan, *supra* note 96. While experts suggest these targets will help head off catastrophe—the central concern of this Note—they will by no means completely resolve the space debris problem.

¹²² Amos, *supra* note 96.

¹²³ *Id.*

¹²⁴ Geier, *supra* note 118.

¹²⁵ Amos, *supra* note 96.

¹²⁶ *Id.*

¹²⁷ *Id.*

¹²⁸ See *Throwing Money Into Space*, *ECONOMIST* (Oct. 26, 2012), <http://www.economist.com/blogs/babbage/2012/10/financing-space-start-ups> [<http://perma.cc/8Q48-FFJH>].

¹²⁹ Cheryl Jones, *ANU taking aim at space junk*, *AUSTRALIAN* (Mar. 8, 2014), available at

are dwarfed by the \$2 billion that Russia's leading space corporation, Energia, is investing in a nuclear-powered pod that it hopes to deploy by 2023.¹³⁰ This pod will fly around space for fifteen years, knocking debris out of the atmosphere using an ion drive.¹³¹

That substantial investments in ADR technologies have seemingly put us on the cusp of possessing the technology to stabilize the space environment significantly undermines claims that incentives to solve the orbital debris problem are lacking because of its nature as a "tragedy of the commons".¹³² Successful implementation of a solution is still years away—and can't be presumed. But taken together with the fact that we likely have a decades-long window to redress the problem,¹³³ Col. Joseph Imburgia's 2011 warning that "a binding international agreement is needed to provide stability and order . . . and to preserve mankind's access to and through space" looks less and less prescient.¹³⁴

B. *The Political Sphere: Efforts to Mitigate Global Climate Change as a Model of Cooperation*

Prior to President Barack Obama's visit to China in the latter part of 2014, expectations for meaningful diplomatic achievements were low.¹³⁵ Thus, the announcement that China and the United States were agreeing to a major climate change accord made huge waves in the global press.¹³⁶ Under the agreement, the United States is pledging to further reduce its greenhouse gas emissions by 2025, while China is aiming to cap its growing

<http://www.theaustralian.com.au/news/health-science/anu-taking-aim-at-space-junk/story-e6frg8y6-1226848446376> [<http://perma.cc/7T5C-SM9K>].

¹³⁰ Julie Beck, *Russia Invests \$2 Billion To Clean Up Space Debris*, POPULAR SCI. (Nov. 29, 2010), <http://www.popsci.com/technology/article/2010-11/russia-invests-2-billion-clean-space-debris> [<http://perma.cc/8ZZ8-R2X5>].

¹³¹ *Id.*

¹³² Laskow, *supra* note 1.

¹³³ Burns, *supra* note 37.

¹³⁴ Imburgia, *supra* note 6, at 634.

¹³⁵ Stuart Leavenworth, *Obama's Trip Exceeds Expectations with Wins on Climate Change, Trade*, MCCLATCHYDC (Nov. 12, 2014), <http://www.mcclatchydc.com/2014/11/12/246595/obamas-china-trip-exceeds-expectations.html> [<http://perma.cc/A7Fj-DCVB>].

¹³⁶ Emily Gosden, *China-US climate change deal a 'giant leap for mankind', says IEA*, TELEGRAPH (Nov. 12, 2014), <http://www.telegraph.co.uk/earth/environment/climatechange/11226716/China-US-climate-change-deal-a-giant-leap-for-mankind-says-IEA.html> [<http://perma.cc/EY2C-Y9PY>].

emissions by 2030.¹³⁷ The International Energy Agency called the agreement “a giant leap for mankind.”¹³⁸

Such an accord might seem far removed from the issue of space debris, but the manner in which the nations of the world address the climate change crisis actually has significant implications for assessing whether similar international cooperation is likely regarding space debris.¹³⁹ The international community's response to climate change is a particularly apt analogue to the space debris crisis because climate change is also seen as a classic tragedy of the commons.¹⁴⁰ It is easy to see why.

The Earth's atmosphere, like outer space, is a finite resource commonly owned by all nations.¹⁴¹ Individual actors—here, defined as entire nations—reap the entire benefit that comes from emitting greenhouse gases.¹⁴² The costs, however, of such emissions, are spread out amongst all nations.¹⁴³ Without regulations, rationally thinking nations seem to lack the incentives to cut back on emissions.¹⁴⁴ Hence, many believe that only a binding treaty that caps emissions can avert a climate crisis.¹⁴⁵ Recent events, however, suggest this isn't necessarily so.

It must first be acknowledged that any argument that climate change is a hopeful model is subject to skepticism for good reason—namely the international community's manifest failure to sufficiently redress the problem.¹⁴⁶ The inadequacy of previous mitigation efforts is illustrated by the fact that, at the current rate of emissions, the Earth's temperature is predicted to rise between 3 to 8 degrees Celsius—with catastrophic results.¹⁴⁷ Climate scientists roundly proclaim that current pledges to reduce emissions are not enough to redress the problem.¹⁴⁸

¹³⁷ David Biello, *Everything You Need to Know about the U.S.-China Climate Change Agreement*, SCI. AM. (Nov. 12, 2014), <http://www.scientificamerican.com/article/everything-you-need-to-know-about-the-u-s-china-climate-change-agreement/> [<http://perma.cc/X6VT-662T>].

¹³⁸ Gosden, *supra* note 136.

¹³⁹ Compare *id.* with Button, *supra* note 2.

¹⁴⁰ Trisolini, *supra* note 92, at 681.

¹⁴¹ Richard N. Cooper, *The Endangered Atmosphere: Preserving a Global Commons*, FOREIGN AFFAIRS (July–Aug. 1997) (book review).

¹⁴² See Trisolini, *supra* note 92, at 681.

¹⁴³ Robert N. Stavins, *Climate Realities*, N.Y. TIMES, Sept. 21, 2014, at SR6.

¹⁴⁴ Trisolini, *supra* note 92, at 681.

¹⁴⁵ David Roberts, *Is there any hope for international climate talks?*, GRIST (Sept. 30, 2012), <http://grist.org/climate-energy/is-there-any-hope-for-international-climate-talks/> [<http://perma.cc/C5Z2-X3R6>].

¹⁴⁶ *Id.*

¹⁴⁷ Stavins, *supra* note 143.

¹⁴⁸ Biello, *supra* note 137.

That troubling fact aside, this Note argues that climate change efforts underway are actually a promising analog for space debris mitigation for two reasons. The first is that, though efforts to date are insufficient, there has been substantial progress made on the issue—and without any binding international regime.¹⁴⁹ For example, in July 2015, China followed up on its 2014 pledge to curb emissions with a detailed plan submitted in anticipation of the Paris climate change conference to be held at the end of the year.¹⁵⁰ On the very same day, the United States and Brazil announced ambitious commitments to increase the percentage of each nation's energy production coming from renewable sources.¹⁵¹ Additionally, Brazil pledged to restore more than 46,000 square miles of its rainforest, an undertaking that will help the planet remove significant amounts of carbon dioxide from its atmosphere.¹⁵² These announcements built the political momentum in the months leading up to the Paris conference. It is important to note, however, that each nation made these commitments voluntarily—and without the pressure of an already existing treaty.¹⁵³

A second important reason for optimism makes that progress particularly impressive: the political and economic challenges presented by climate change seem far more intractable than those presented by the issue of space debris.¹⁵⁴ As with the issue of space debris, countries do not equally share the blame for causing the planet to warm.¹⁵⁵ But balancing the equities with respect to global warming is profoundly vexing. For instance, just how much economic pain should nations like China (the world's leading emitter of greenhouse gases) and India be required to endure, especially considering that so many Western nations have already reaped almost two centuries of benefits from their unchecked burning of fossil fuels?¹⁵⁶

In the United States, added to the potential economic costs of addressing climate change is the fact that a large percentage of the American populace simply does not believe that human beings are responsible for the steady rise in the Earth's temperature.¹⁵⁷ Fortunately, denial of

¹⁴⁹ Roberts, *supra* note 145.

¹⁵⁰ Chris Mooney & Steven Mufson, *In a Major Moment for Climate Policy, China, Brazil, and the U.S. All Announce New Commitments*, WASH. POST, June 30, 2015, at A6.

¹⁵¹ *Id.*

¹⁵² *Id.*

¹⁵³ *Cf. id.*

¹⁵⁴ Compare Stavins, *supra* note 143, with Laskow, *supra* note 1.

¹⁵⁵ *Cf.* Stavins, *supra* note 143.

¹⁵⁶ *See id.*

¹⁵⁷ *Id.*; Lydia Saad, *A Steady 57% in U.S. Blame Humans for Global Warming*, GALLUP

the problem is not an obstacle to stabilizing the amount of debris in space. Moreover, it is noteworthy that, in the midst of a fraught political atmosphere, President Obama has been able to advance U.S. efforts to combat climate change on a number of fronts.¹⁵⁸

While the global community will continue to grapple with climate change for some time, the substantial cooperation that is emerging on the issue bodes well for the ability of spacefaring nations to handle a difficult, but undeniably more straightforward problem.

C. *Rethinking Theory: Economic Models Point to International Cooperation Even Without a Binding Treaty*

The progress already being made on the space debris problem and on the analogous problem of climate change is cause for optimism. If the economic theories many commentators rely upon are correct, this should come as quite a shock.¹⁵⁹ However, a reexamination of common assumptions about how economic theory applies to the space debris problem removes any cause for surprise and, in fact, is one more cause for optimism that the tragedy of the commons can be avoided in orbital space.

1. The Prisoner's Dilemma

Tragedies of the commons are often conceived of as "prisoner's dilemmas," a concept arising out of game theory.¹⁶⁰ Perhaps not surprisingly, both global warming and the space debris crisis have been labeled as such.¹⁶¹ This is a pessimistic label that does not apply to these issues, however.¹⁶²

(Mar. 18, 2014), <http://www.gallup.com/poll/167972/steady-blame-humans-global-warming.aspx?version=print> [<http://perma.cc/HPW9-L5T3>].

¹⁵⁸ See generally Suzanne Goldenberg, *Barack Obama Sets Sizzling Climate Action Pace in Push to Leave Legacy*, THE GUARDIAN (June 26, 2015), <http://www.theguardian.com/environment/2015/jun/25/barack-obama-climate-change-legacy> [<http://perma.cc/7X4Q-UVVC>].

¹⁵⁹ Plumer, *supra* note 38.

¹⁶⁰ Elinor Ostrom, *A Polycentric Approach for Coping with Climate Change* 7 (World Bank, Policy Research Working Paper No. 5095, 2009), available at <http://www.iadb.org/intal/intalcdi/pe/2009/04268.pdf> [<http://perma.cc/AK53-VEUN>].

¹⁶¹ Shackelford, *supra* note 3, at 508; David Finkleman, *The Prisoner's Dilemma in Space*, SPACENEWS.COM (May 20, 2013), <http://spacenews.com/35403the-prisoners-dilemma-in-space/> [<http://perma.cc/2FNS-LP9G>].

¹⁶² Daniel H. Cole & Peter Z. Grossman, *Institutions Matter! Why The Herder Problem is Not*

The classic prisoner's dilemma poses players (who need not be prisoners) with a simple choice: "cooperate" or "defect."¹⁶³ As applied to Hardin's quintessential illustration of a tragedy of the commons, a player "cooperates" by limiting the number of cattle she brings to pasture.¹⁶⁴ On the other hand, by deciding to bring more cattle to the pasture, a player "defects."¹⁶⁵ Based upon the presumption that players are acting in their rational self-interest, game theory posits that a prisoner's dilemma will result in both players defecting.¹⁶⁶ In a situation where a common pool resource is at risk of being overused, repeated defections among its users will invariably lead to the destruction of the common pool resource.¹⁶⁷

The underlying forces of the prisoner's dilemma seem to be the same as those identified by Hardin: rational players recognize that they internalize all of the benefits of defection but externalize much of the benefits of cooperation.¹⁶⁸ Understanding that other self-interested players face the same calculus, each player will refuse to let other players benefit from her own cooperation—a move that would simultaneously reduce her own "payout."¹⁶⁹

The prisoner's dilemma is commonly illustrated by a diagram containing four cells, each of which describes a possible outcome of the game.¹⁷⁰ The first cell describes the respective payouts to Players A and B if they both cooperate. Using hypothetical numeric values to represent the payouts, the first cell might read, "(A)4, (B)4"—for a collective payout of '8.'¹⁷¹ The second cell represents the outcome if Player A cooperates but Player B defects, and might read "(A)0, (B)6."¹⁷² The third cell represents the inverse: Player A defects but Player B cooperates. This cell might

a Prisoner's Dilemma, 69 *THEORY & DECISION* 219, 219 (2010), available at <http://link.springer.com/article/10.1007%2Fs11238-008-9121-3#page-1> [<http://perma.cc/ZCD4-JVPR>].

¹⁶³ ROBERT C. ELLICKSON, *ORDER WITHOUT LAW: HOW NEIGHBORS SETTLE DISPUTES* 160 (1991). There other variations, such as "shirk" or "work". *Id.*

¹⁶⁴ See Fennell, *supra* note 43, at 945.

¹⁶⁵ *Id.*

¹⁶⁶ ELLICKSON, *supra* note 163, at 161.

¹⁶⁷ See *Prisoner's Dilemma*, STAN. ENCYCLOPEDIA OF PHIL. (Aug. 29, 2014) <http://plato.stanford.edu/entries/prisoner-dilemma/> [<http://perma.cc/5Y2V-RE57>].

¹⁶⁸ See Fennell, *supra* note 43, at 914. This principle can also be conversely framed as internalizing all of the costs of cooperation while externalizing the costs of defection.

¹⁶⁹ See ELLICKSON, *supra* note 163, at 160–61.

¹⁷⁰ *Id.*

¹⁷¹ *Cf. id.* Author altered the values Ellickson used while maintaining the internal logic of the game.

¹⁷² *Cf. id.*

read "(A)6, (B)0."¹⁷³ Finally the fourth cell, representing the outcome if both players defect, might read, "(A)2, (B)2."¹⁷⁴

The setting of values here is arbitrary, of course, but the idea is that a situation is only properly termed a "prisoner's dilemma" if the outcomes mirror those described above.¹⁷⁵ The requisite principles are as follows: (1) mutual cooperation (Cell 1) yields the greatest *collective* payout, (2) mutual defection (Cell 4) yields the lowest collective payout, and (3) each player gains the highest *individual* payout when she defects while the other player cooperates (Cells 2 and 3).¹⁷⁶

Clearly, if Player A is motivated solely by her own self interest, she would prefer the outcome described in Cell 3, which contains her highest payout—and which results from her own defection and Player B's cooperation.¹⁷⁷ Short of that ideal outcome, however, one can also see that both players would far prefer the results of mutual cooperation (each realizing a payout of '4') to the results of mutual defection (each realizing a payout of '2'). Why then, does the prisoner's dilemma result in the lowest collective payout possible and individual payouts lower than those that would accrue if both players cooperated?

A crucial criterion of the prisoner's dilemma is that players make their choices both instantaneously and independently.¹⁷⁸ In other words, there is no room for negotiation.¹⁷⁹ In these circumstances, whether Player A guesses that Player B will defect or cooperate, Player A knows that her payout will be higher in either case if she defects herself.¹⁸⁰ It therefore appears that the only "rational" move is to defect.¹⁸¹ The insidious irony of the prisoner's dilemma is that Player B is faced with the identical scenario, so both will make choices leading to poor individual and collective outcomes.¹⁸²

¹⁷³ *Cf. id.*

¹⁷⁴ *Cf. id.*

¹⁷⁵ See ELLICKSON, *supra* note 163, at 160.

¹⁷⁶ *See id.*

¹⁷⁷ And, of course, the same logic would cause a self-interested B to want the inverse outcome of Cell 2.

¹⁷⁸ Ostrom, *supra* note 160, at 7.

¹⁷⁹ *See id.*

¹⁸⁰ ELLICKSON, *supra* note 163, at 161. For example, if Player B cooperates, Player A knows that her own defection will yield her a payout of 6, whereas her cooperation will yield her only 4. If Player B defects, she will receive a payout of either 0 or 2—the higher value if she defects.

¹⁸¹ This fact makes defection in a prisoner's dilemma what game theorists refer to as the "dominant" move. *Id.* at 159–60.

¹⁸² *Id.* at 159–61.

If we apply the logic of the prisoner's dilemma to the issue of space debris, each nation will seemingly realize that its best outcome would be to defect while other countries cooperate.¹⁸³ Here, defection could include refusing to take costly precautions to avoid increasing the amount of debris in orbit and failing to subsidize the development of ADR technologies.¹⁸⁴ Because each nation will predict that other nations will similarly see the value in defecting, each will decide that cooperation is a fool's errand.¹⁸⁵ Or so the theory goes.

2. The Unlocked Cell: Other Limitations of the Prisoner's Dilemma

A careful analysis reveals that the problem of space debris is not, in fact, a prisoner's dilemma.¹⁸⁶ Furthermore, by more accurately identifying the payouts of cooperation-defection scenarios, it becomes clear that each party's rationality—a key premise of game theory—should actually encourage its cooperation.

One glaring problem with labeling the space debris problem as a prisoner's dilemma is that the game assumes that the players do not speak to each other while deciding whether or not to cooperate.¹⁸⁷ With respect to spacefaring nations and the issue of debris, no such condition is imposed, of course.¹⁸⁸ To the contrary, attempts to move towards a treaty (though feeble), the development of UN protocols regarding space debris, and international investments in removal technology demonstrate the existence of robust communication amongst the principal actors.¹⁸⁹

Even the possibility of communication between parties dramatically alters the dynamics of the prisoner's dilemma because it opens the door to negotiation.¹⁹⁰ If parties recognize that a mutually poor outcome is more likely than their ideal outcomes,¹⁹¹ they each have every incentive

¹⁸³ These opportunists are termed “free riders” and pose a significant problem to collective action problems, discussed *infra*. Ostrom, *supra* note 160, at 8.

¹⁸⁴ See Fennell, *supra* note 43, at 914–15 (explaining that commons fall prey not only to overuse, but underinvestment).

¹⁸⁵ See ELLICKSON, *supra* note 163, at 160–61.

¹⁸⁶ See generally Cole & Grossman, *supra* note 162.

¹⁸⁷ Ostrom, *supra* note 160, at 7.

¹⁸⁸ *Mitigation Guidelines*, *supra* note 66. The COPUOS guidelines are one obvious example of robust international discourse.

¹⁸⁹ *Id.*; see discussion *supra* Part III.A.

¹⁹⁰ Ostrom, *supra* note 160, at 12.

¹⁹¹ See *supra* Part III.C.1 (Cell 4 shows the mutually poor outcome. Ideal outcomes are shown in Cells 2 and 3 for Players A and B, respectively).

to work towards a compromise that achieves an outcome in the middle of these extremes.¹⁹² In other words, they will seek a compromise where, by mutual cooperation, they attain the highest collective payout and, in a common pool resource scenario, avoid resource depletion.¹⁹³

Furthermore, a crucial limitation of the typical prisoner's dilemma is that it fails to capture the nature of many tragedies of the commons—those that risk the total destruction of the usefulness of a vitally important shared resource.¹⁹⁴ If parties are able to appreciate this impending, and dramatic, change in payouts (i.e., foresee the tragic outcome and roughly calculate its costs), their rational self-interest will suggest a different course of action than otherwise expected.

Reframed in another way, in the short term, the dynamics of a prisoner's dilemma would indeed seem to suggest that each party's "dominant"¹⁹⁵ move is to defect and take advantage of the other party's cooperation. However, if the players are aware of the impending destruction of the commons and factor this into their decision-making, rational and self-interested decision-making no longer resembles a prisoner's dilemma.

This point can be illustrated by applying Hardin's pasture hypothetical to two farmers.¹⁹⁶ Let us assume that the individual benefit of adding an additional cow to the pasture is '5,' and that the collective cost of each additional cow is '6'—and thus '3' for each player. The resulting payouts can be described as follows: Cell 1, "(A)0, (B)0"; Cell 2, "(A)-3, (B)2"; Cell 3, "(A)2, (B)-3"; and Cell 4, "(A)-1, (B)-1." These outcomes meet the criteria of a prisoner's dilemma: the highest collective payout results from cooperation (Cell 1), the lowest collective payout arises from mutual defection (Cell 4), and the highest individual payouts result from one player defecting while the other cooperates (Cells 2 and 3).¹⁹⁷

The logic of the prisoner's dilemma dictates that each player will selfishly add another cow to the pasture.¹⁹⁸ And if the anticipated payout remains the same, they will continue to add cows in future iterations of the game.¹⁹⁹ But what if the players realize that at some uncertain point

¹⁹² *Id.* (represented by Cell 1).

¹⁹³ See Cole, *supra* note 162, at 227.

¹⁹⁴ *Id.* at 223–25.

¹⁹⁵ ELLICKSON, *supra* note 163, at 159–60.

¹⁹⁶ Obviously more than two actors are involved in the space debris problem, but this two-person scenario simply and clearly illustrates a principle that applies to multiplayer games.

¹⁹⁷ It should be noted that "payouts" can actually be "costs"—which are reflected in the negative numbers. See Fennell, *supra* note 43, at 945.

¹⁹⁸ *Id.*

¹⁹⁹ *Id.* at 961 (averring that "[i]f a player's perception of the payoffs changes, the game changes").

in the near future the addition of more cows will utterly destroy the pasture? Furthermore, what if the farmers depend entirely on the pasture for their subsistence? If this is the case, the farmers will calculate that they risk a payout scenario that looks gravely different than that described above. The complete destruction of the pasture will result in costs that far exceed the values in the cells above, perhaps '100' collectively—or '50' to each farmer. Even if we generously assume that the farmers were still able to realize the benefit of adding an additional cow ('5') before the pasture's destruction, the following payouts would result: Cell 1, "(A)0, (B)0"; Cell 2, "(A)-50, (B)-45"; Cell 3, "(A)-45, (B)-50"; and Cell 4, "(A)-45, (B)-45."²⁰⁰

The values in the cells above reflect a stark potential outcome of a tragedy of the commons: the only possible way to avoid a payout of colossal costs is to mutually cooperate.²⁰¹ A two-person prisoner's dilemma game cannot accurately describe the dynamic between numerous actors sharing a common resource, where there is often a certain number of cooperating players needed to stave off the destruction of the resource.²⁰² What the two-player hypothetical does capture accurately, however, is the way that defecting players "roll the die": they may receive a beneficial payout, but they also risk catastrophe.²⁰³ As the tipping point for that abject payout appears closer, rational actors will find ever-increasing incentive to cooperate.

3. The Free-Rider Problem

Another vexing element of communal resource problems merits attention. This is the problem of "free riders," those who would defect and reap the benefits of parties who choose to cooperate in avoiding the tragedy of the commons.²⁰⁴ Aside from being morally galling, the existence of these opportunists certainly leads to less than optimal outcomes,

²⁰⁰ This payout scheme reflects the point where the addition of one more cow will cause the destruction of the pasture. Therefore, the costs of such destruction are not doubled by both players' defection.

²⁰¹ Mutual cooperation may result in a short-term cost, but presumably yields a large benefit for a common property with value.

²⁰² *Prisoner's Dilemma*, *supra* note 167 (proposing an alternate payout matrix where multiple actors share a common resource at risk of overuse).

²⁰³ With regard to space debris, a large degree of uncertainty exists regarding the timing of an irreversible cascading effect. *Prisoner's Dilemma* also identifies the (potential) uncertainty regarding the number of players whose cooperation is needed to avoid the tragedy of the commons. *Id.*

²⁰⁴ Ostrom, *supra* note 160, at 8.

which can only be achieved if everyone pitches in (or shows restraint, depending on the nature of the problem).²⁰⁵ The big fear, however, is that, perhaps even after cooperation has already begun, the presence of free riders will put the group back on the path towards the tragedy of the commons.²⁰⁶ Who in their right mind, after all, would choose to continue receiving the “sucker’s payout” of cooperation while another takes full advantage of his magnanimity?²⁰⁷ Actually, common sense suggests that you and I might.

Imagine that you are in a sinking fishing boat with five other people. You’re approaching the shore, but the only way you can make it back to safety is if several of you bail out the water. You all have buckets, so everyone gets to work. Everyone except Lazy Pete, that is. No doubt you’ll all resent Lazy Pete’s inaction, but will you all follow his lead? Probably not if the stakes (here, your life) are high enough.²⁰⁸

This intuitive answer is, in fact, born out in Professor Elinor Ostrom’s research.²⁰⁹ In experiments and field studies of collective action problems, Ostrom and her colleagues did observe some free riders, but found that more individuals cooperate than might be expected.²¹⁰ Ultimately, whether one will internalize extra costs where others reap undeserved benefits is just another facet of the cost-benefit analysis.²¹¹ The higher the stakes are, the more unlikely it is that free riders will discourage the cooperation of others; and the less likely it is that actors will free ride in the first place.

IV. THE PIVOT: FROM AVOIDING CATASTROPHE TOWARDS ACHIEVING OPTIMAL OUTCOMES

Modern economic scholarship challenges the assumption that solutions to common interest tragedies necessitate an external authority imposing rules on resource users.²¹² And the facts on the ground amply demonstrate that progress is being made toward a solution to the space debris problem.²¹³ But although alarmist calls for a treaty may be

²⁰⁵ *Id.*

²⁰⁶ *See id.*

²⁰⁷ *See* Fennell, *supra* note 43, at 945.

²⁰⁸ It is more efficient if everyone helps out, and so the results might be termed “sub-optimal.” But the salient point is that the tragic result is avoided. *Id.* at 941.

²⁰⁹ Ostrom, *supra* note 160, at 10.

²¹⁰ *Id.*

²¹¹ *See* Fennell, *supra* note 43, at 943.

²¹² Ostrom, *supra* note 160, at 5.

²¹³ *See supra* Part III.A.

overwrought, the progress being made should not lead U.S. policymakers to rest on their laurels. The first section of Part IV explains why a sense of urgency should still guide space debris mitigation efforts. Section B summarizes economic theories that explain how to facilitate cooperation amongst community members facing a common resource problem. Finally, Section C applies these theories regarding cooperation to the problem of orbital debris.

A. *The Exigency Remains*

With respect to some common resource problems, the prospect of continued cooperation may be enough to suggest a successful resolution to the issue. Say, for example, that the farmers from Hardin's pasture recognize the threat of overgrazing and, after some negotiation, agree to slow the introduction of new cattle to sustainable levels. This would seem to resolve the issue. As long as farmers abide by that agreement, they will avoid the tragedy of the commons.

Achieving a more or less permanent solution to the space debris problem is not as straightforward. The reason is that even as the space debris problem is being redressed, the risk of space objects colliding remains as long as there are uncontrolled objects whizzing around the Earth's atmosphere.²¹⁴ With millions of such objects now in orbit, this will indeed be the case for a very long time.²¹⁵

Improved tracking capabilities, avoidance maneuvers, and (eventually) ADR technologies all work together to make such collisions less likely. However, no remediation can remove the risk of accidents altogether, and some collisions could have devastating effects: the destruction of even one large satellite could double the amount of space debris in orbit.²¹⁶ Of course, any such increase in the amount of debris in orbit then renders other collisions more likely to occur.²¹⁷ It is thus possible that after a number of years making progress towards reaching a sustainable level of debris, a stroke of bad luck could rapidly undo such progress and unleash the dreaded Kessler Syndrome.²¹⁸

That said, the risk of such an unwelcome series of events is no cause for despair. If cooperative mitigation efforts continue, the "odds are

²¹⁴ Cf. Fuentes, *supra* note 12.

²¹⁵ *Id.*

²¹⁶ Shackelford, *supra* note 3, at 495.

²¹⁷ See Plumer, *supra* note 38.

²¹⁸ See *id.*

ever in our favor” that a tragedy of the space commons can be avoided.²¹⁹ Considering the paramount importance of the space commons, it is in the interest of spacefaring nations to act with haste to improve those odds.

The second reason for states to act with urgency is not unconnected to the first. The longer we wait to solve the space debris problem, the more expensive the solution becomes.²²⁰ For example, while experts estimate that the removal from orbit of just five space objects per year could stabilize the situation in Earth’s atmosphere, that number will only increase with the introduction of more space debris.²²¹ Therefore, even if a large collision somehow does not set off a cascading chain of collisions, it will certainly dramatically increase the cost of remediation.

B. *Encouraging Cooperation*

In his seminal work, *Order Without Law*, economist Robert Ellickson described the way that cattle ranchers in Shasta County, California, developed extrajudicial norms to govern liability for cattle trespasses and to cooperate on fence building and maintenance.²²² From his observations of this cooperation amongst ranchers, Ellickson developed a hypothesis that has implications for effectively remediating the space debris problem.²²³

Ellickson’s hypothesis is predictive: “members of a close-knit group develop and maintain norms whose content serves to maximize the aggregate welfare that members obtain in their workaday affairs with one another.”²²⁴ This hypothesis is startlingly optimistic in two ways. First, it avers that the group itself will develop these norms, removing the need for an external authority (akin to a treaty) to impose a regulatory regime.²²⁵

Second, the hypothesis claims that the resulting norms will not merely be workable, but that they will “maximize the aggregate welfare.”²²⁶ Ellickson’s broad definition of “welfare” encompasses economic benefits and other desired outcomes.²²⁷ In the context of space debris

²¹⁹ See generally Suzanne Collins, *THE HUNGER GAMES* (Lionsgate 2012) (paraphrasing, of course).

²²⁰ See Sheahan, *supra* note 96.

²²¹ Amos, *supra* note 96.

²²² See generally ELLICKSON, *supra* note 163.

²²³ *Id.* at 167.

²²⁴ *Id.* at 165.

²²⁵ See generally *id.*

²²⁶ *Id.* at 167.

²²⁷ *Id.* at 170.

remediation, welfare maximization would include economically efficient operational norms and the timely development of practicable debris removal technologies.

Another term from Ellickson's hypothesis deserves attention, for it may seem that spacefaring nations are hardly a "close-knit community."²²⁸ Ellickson's definition of this term, however, belies its bucolic connotation. For Ellickson's purposes, close-knittedness is defined by the sharing of both information and of informal power (such as that of applying sanctions) and by the ongoing nature of relationships amongst members.²²⁹

Defined this way, the community of space faring nations would indeed seem to be "close-knit."²³⁰ Certainly, there are ongoing iterations in the "game" of spacefaring, and nations regularly employ what Ellickson calls "self-help" remedies when other nations prove uncooperative.²³¹ Further, substantial information sharing is evident from the cooperative efforts of COPUOS and the Inter-Agency Space Debris Coordination Committee.²³²

Nonetheless, whether or not a community is "close-knit" might not always be amenable to a simple "yes" or "no" answer.²³³ Crucial differences between spacefaring nations and the Shasta County ranchers make it impossible to assume similarly effective cooperation will result. For one, while both "games" have multiple iterations, Ellickson was studying norms that had developed over many decades.²³⁴ The cattle grazing and fence-building norms also presumably evolved naturally over time. With respect to space debris, the risks of catastrophic collisions add a unique element of time pressure to norm formation.²³⁵

²²⁸ ELLICKSON, *supra* note 163, at 193–94.

²²⁹ *Id.* at 177–81. Using the language of game theory, and specifically the *Prisoner's Dilemma*, Ellickson speaks of the ongoing relationships as games with "iterated" play. This is yet another reason that tragedies of the commons are not classic prisoner's dilemmas, which involve what Ellickson calls "single-shot" play. *Id.* at 55.

²³⁰ See ELLICKSON, *supra* note 163, at 193–94.

²³¹ For a discussion on Robert Axelrod's theory of "tit-for-tat" as applied to another area of international relations, see generally Barbara Dluhosch & Daniel Horgos, (*When*) *Does Tit-for-Tat Diplomacy in Trade Policy Payoff?* (Helmut Schmidt University, Working Paper No. 116, 2012).

²³² The latter group is comprised of NASA and twelve other such space agencies. Their mission is "to facilitate opportunities for cooperation in space debris research, to review the progress of ongoing cooperative activities, and to identify debris mitigation options." IADC (Aug. 24, 2015), <http://www.iadc-online.org> [<http://perma.cc/2V83-2NTX>].

²³³ ELLICKSON, *supra* note 163, at 193–94.

²³⁴ *Id.* at 30, 43.

²³⁵ See *supra* Part IV.A.

Moreover, with respect to space debris, it may not be sufficient to control norms with the same degree of effectiveness as that achieved by the ranchers. This point is illustrated by the story of Frank Ellis, a latecomer to the Shasta County ranching business.²³⁶ Ellis frequently flouted the ranchers' tacit rules, instigating numerous conflicts with his neighbors.²³⁷ The informal sanctions employed by ranchers, usually so effective, had no effect on Ellis.²³⁸ Despite their troubles, life went on for the residents of Shasta County—even if many were happy to see Ellis depart after several years.²³⁹ As demonstrated by the destruction of the Chinese satellite, one rogue actor in the space arena is far more dangerous.²⁴⁰

C. *From Predictive to Remedial: Using Theory to Achieve Optimal Results*

To whatever degree spacefaring nations constitute a “close-knit community,” policymakers would be wise to proactively strengthen the bonds amongst these international actors. Elinor Ostrom's work, which seems to build on Ellickson's hypothesis, can serve as a starting point in this endeavor.

Ostrom identifies several variables that together predict the likelihood of cooperation amongst actors facing a collective action problem.²⁴¹ Factors that point to cooperation include a common belief in the importance of the resource, the possession of reliable information, shared past successes, a desire among actors to be seen as trustworthy, and means of applying sanctions.²⁴² These factors are highly consistent with—if not more fleshed out than—Ellickson's definition of a “close-knit” community.²⁴³

Ostrom views her work not merely as predictive, but as a roadmap to effectively address collective action problems.²⁴⁴ Ostrom advocates a “polycentric” approach to solving problems of the global commons.²⁴⁵ As opposed to a regime governed by a central authority, polycentric decision-making occurs amongst diverse, smaller, and sometimes overlapping

²³⁶ ELLICKSON, *supra* note 163, at 33.

²³⁷ *Id.* at 33–39.

²³⁸ *Id.* Interestingly, gossip among neighbors was a sufficient sanction. *Id.*

²³⁹ *Id.* at 38–39.

²⁴⁰ Button, *supra* note 2, at 546.

²⁴¹ Ostrom, *supra* note 160, at 12.

²⁴² *Id.*

²⁴³ ELLICKSON, *supra* note 3, at 177–81.

²⁴⁴ *See generally* Ostrom, *supra* note 160.

²⁴⁵ *See id.*

actors.²⁴⁶ The actors could be individual nations, regional groups, or multinational organizations.²⁴⁷ Ostrom has, pertinently, applied this polycentric approach to another potential tragedy of the global commons—climate change.²⁴⁸ And even more germane is Professor Scott Shackelford's recent assertion that a polycentric regime is emerging with respect to the space commons.²⁴⁹

It seems likely that Ellickson would simply view polycentric regimes as a unique, and complex, iteration of a “close-knit” community.²⁵⁰ That said, the question of how to strengthen the bonds of members of the space faring community is an apt one.

Facilitating the sharing of information amongst spacefaring parties would almost certainly be at the top of the list. Both Ellickson and Ostrom emphasize the importance of the free flow of reliable information between actors.²⁵¹ It is, after all, the lack of information-sharing that is a key reason why a true prisoner's dilemma engenders noncooperation.²⁵² Information regarding the threat posed by debris is particularly critical, as it is paramount to avoid collisions—especially where advance notice is possible.²⁵³

Obligatory sharing of information is also one of the most prominent elements of Col. Imburgia's proposals for a binding space debris treaty.²⁵⁴ In an article insisting upon the need for such a treaty, Imburgia calls for a comprehensive registry of space objects, the dissemination of tracking data, and cooperation in developing ADR technologies.²⁵⁵ For Imburgia, the sharing of information is one of the primary *goals* of a centralized (treaty) regime, whereas for Ellickson and Ostrom, information sharing is a *precondition* of fostering cooperation in a non-centralized regime.²⁵⁶

Another aspect of cooperative communities, important to Ellickson and Ostrom, deserves the close attention of policymakers: the sanctioning

²⁴⁶ *Id.* at 34–36.

²⁴⁷ Shackelford, *supra* note 3, at 469.

²⁴⁸ *See generally* Ostrom, *supra* note 160.

²⁴⁹ *See generally* Shackelford, *supra* note 3.

²⁵⁰ Ellickson's definition of “close-knit,” as discussed above, does not mirror common usage. Ellickson says, for example, that the term can apply to large urban populations. ELLICKSON, *supra* note 163, at 182.

²⁵¹ *Id.* at 180–81; Ostrom, *supra* note 160, at 11–12.

²⁵² Cole, *supra* note 162, at 220–23.

²⁵³ Hollandsworth, *supra* note 8, at 12.

²⁵⁴ Imburgia, *supra* note 6, at 639–40.

²⁵⁵ *Id.*

²⁵⁶ ELLICKSON, *supra* note 163, at 180–81; Imburgia, *supra* note 6, at 626, 639; Ostrom, *supra* note 160, at 11–12.

powers of community members.²⁵⁷ One can imagine the types of sanctions that would adequately respond to modest transgressions, such as the refusal to share data or the failure to follow a certain protocol that prevents the formation of new space debris. Perhaps one nation might answer these misbehaviors by withdrawing cooperation from a joint space project or by refusing to award a coveted contract.²⁵⁸ But how would the community respond to another deliberate act of destruction like the ASAT test carried out by the Chinese in 2007?²⁵⁹ Nations have every incentive not to perform such a reckless act, but the possibility that a rogue actor might be tempted to such intransigence demands that other nations have appropriate penalties at the ready. "Community members" should place the development of potential at-the-ready sanctions towards the top of their agendas.

CONCLUSION

The potential consequences of the space debris crisis could hardly be more grave, implicating the fabric of both our daily lives and our national security apparatus. Recognizing these high stakes, and identifying the problem of orbital debris as a tragedy of the commons, numerous commentators have claimed that a comprehensive treaty to redress the issue is imperative.

The lack of meaningful progress towards such a treaty is no call for alarm, however. Economists are reevaluating assumptions regarding common resource problems, resulting in a much more optimistic outlook with respect to when actors will cooperate. While some find voluntary cooperation on the issue of space debris counterintuitive, it really is common sense. The actors involved recognize clearly that shortsighted, self-interested actions will lead to a terrible disaster that they could only regret.

The cooperation that is under way to solve this problem is consistent with the analyses of economists like Robert Ellickson and Elinor Ostrom. However, it is vital that policymakers not assume that progress already made assures that catastrophe will be averted. Instead, they should deliberately cultivate the preconditions that these economists suggest facilitate cooperation.

²⁵⁷ Ostrom, *supra* note 160, at 12; ELLICKSON, *supra* note 163, at 178–79.

²⁵⁸ Hollandsworth, *supra* note 8, at 19.

²⁵⁹ *Id.* at 18 (noting the failure of states to apply sanctions to China).