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PAPER TITLE

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Extended Abstract—

In recent years, the growing awareness of potential threats posed by near-Earth objects (NEOs) has led to increased interest in developing and implementing planetary defense measures. International cooperation and public support are crucial to ensuring the long-term success of planetary defense initiatives. However, a number of economic, political, legal, and social issues stand in the way of effective large-scale cooperation in pursuing planetary defense.

The growing number of satellites in Earth's orbit, coupled with the militarization of space, raises the stakes for international coordination in identifying and mitigating cosmic threats. As nations invest in their space capabilities, the potential for conflicts of interest and mistrust may hamper cooperative efforts, even as the need for such collaboration becomes more pressing. Moreover, the lack of established international norms and legal frameworks specifically addressing planetary defense compounds these challenges, leaving gaps in responsibility, liability, and decision-making authority. The success of planetary defense initiatives also hinges on public support and awareness, as these factors can influence resource allocation and the prioritization of investments in relevant technologies. Despite the potentially catastrophic consequences of an unmitigated NEO impact, public perception of these threats is often influenced by psychological factors that can cause the public to underestimate the risks posed by NEOs and other planetary threats.

This article examines the major challenges to international cooperation in planetary defense. The article begins by considering the major types of collective action problems facing international collaboration planetary defense, focusing on the “free rider problem” as a major challenge to the success of planetary defense initiatives. For example, all countries have an interest in minimizing costs devoted to international initiatives. Moreover, collaborating to reduce the risk of satellite-related debris requires international transparency that may conflict with parties’ interest in keeping confidential information related to national security or economic policy. This article will then analyze the legal and economic aspects of these cooperation problems, and will consider various possible strategies for avoiding cooperative challenges and increasing collective buy-in. Noteworthy solutions worth considering include the use of treaties as pre-commitment devices, which parties agree to undertake in order to limit their future options and commit themselves to pre-established lines of conduct. Additional considerations include the use of principles from the behavioral economics movement, such as the use of opt-in versus opt-out policies and other tactics to reduce the effects of cognitive biases by governmental decision makers.

1. Introduction

Planetary defense is an increasingly common talking point in international politics. While many nations have expressed their nominal willingness to collaborate in addressing the threats posted by near-earth objects (“NEOs”) and other planetary risks, few nations have taken steps to commit themselves to national or international planetary defense policies. Without widespread commitment, such initiatives run the risk of being too poorly funded or coordinated to succeed.

One major source of resistance to international planetary defense collaboration involves the cooperative and competitive dynamics of multinational action. Various collective action problems face national and international actors in their efforts to collaborate in preempting planetary threats. One famous example of a collective action problem is the “tragedy of the commons,” in which many parties have a common interest in cooperating but each party has a greater incentive to exploit the efforts of the collective [1]. Although there is precedent in international law for global cooperation in responding to planetary threats, making these commitments effective will require international bodies addressing the competitive dynamics between nations with a common interest in planetary defense.

Collective action problems are common when dealing with anthropogenic planetary risks. Economist and Nobel Prize laureate Thomas Schelling explored the cooperative dynamics of international attempts at environmental reform [2]. If this problem faces us when confronting planetary dangers that have already begun, how much more so when considering planetary risks that, at least as of now, remain far in the future.

This article examines the cooperative dynamics of planetary defense. The article begins by considering the major types of collective action problems facing international collaboration planetary defense, focusing on the "free rider problem" as a major challenge to the success of planetary defense initiatives. For example, all countries have an interest in minimizing costs devoted to international initiatives. Moreover, collaborating to reduce the risk of satellite-related debris requires international transparency that may conflict with parties' interest in keeping confidential information related to national security or economic policy

This article will then analyze the legal and economic aspects of these cooperation problems, and will consider various possible strategies for avoiding cooperative challenges and increasing collective buy-in. Noteworthy solutions worth considering include the use of treaties as pre-commitment devices, which parties agree to undertake in order to limit their future options and commit themselves to pre-established lines of conduct. Additional considerations include the use of principles from the behavioral economics movement, such as the use of opt-in versus opt-out policies and other tactics to reduce the effects of cognitive biases by governmental decision makers.

2. Collective action problems for defense against NEOs

While public awareness of the need for planetary defense measures continues to grow, it is not growing fast enough to put the needed pressure on government actors to prioritize these measures. Not only do elected officials not have a strong incentive to pursue planetary defense initiatives, but doing so might even alienate them from voters who want to see their representatives focus on issues with shorter time horizons.

Planetary defense requires extensive funding and investment of national resources. No country will want to incur these sorts of costs if it believes there to be a possibility that other countries will be independently willing and able to do so. This constitutes a "free rider" problem, in which the international community struggles to gather the total resources needed for effective planetary defense initiatives, with each party withholding in the hope that others will cover the costs.

Planetary defense technologies require investment and cooperation among nations to effectively address the global threat posed by near-Earth objects (NEOs) and other cosmic hazards. Some examples of planetary defense technologies include:

- Ground-based telescopes and surveys: Upgrading and expanding ground-based telescope networks and surveys, such as the Panoramic Survey Telescope and Rapid Response System (Pan-STARRS) and the Large Synoptic Survey Telescope (LSST), can enhance the detection and tracking of NEOs. These observatories require investment in infrastructure, advanced instrumentation, and international data-sharing agreements to operate effectively.

- Space-based telescopes: Deploying space-based telescopes, such as the Near-Earth Object Surveillance Mission (NEOSM) and the European Space Agency's (ESA) Hera mission, can provide more accurate detection and monitoring capabilities. These missions require significant investments in spacecraft development, launch services, and international collaboration for data sharing and analysis.

- Research and development: Investments in research and development can help advance our understanding of NEOs, their composition, and their potential impact on Earth. This includes funding for laboratory studies, simulations, and analysis to improve our knowledge of asteroid deflection and disruption techniques.

- Early warning systems: Developing and implementing early warning systems to alert nations of impending NEO impacts can help in emergency preparedness and response. Establishing a global network of sensors and communication infrastructure, along with international protocols for information sharing and decision-making, is crucial for effective early warning systems.

- Deflection and disruption technologies: Developing and testing deflection and disruption technologies is essential for mitigating the threat posed by NEOs. Some examples include:

    - Kinetic impactors: The Double Asteroid Redirection Test (DART) mission by NASA and the Hera mission by the ESA aim to test the effectiveness of kinetic impactors in deflecting asteroids.

- Gravity tractors: This method involves using a spacecraft's gravity to slowly pull an asteroid off its collision course with Earth.
- Nuclear devices: Although controversial, using nuclear devices to deflect or disintegrate an asteroid is a potential option for addressing large or imminent threats.
- Laser ablation: This technique involves using high-powered lasers to vaporize the surface of an asteroid, creating a jet of gas and debris that pushes the asteroid off its trajectory.

Moreover, countries may be reluctant to invest national resources if they believe other countries will attempt to free-ride off of their efforts or otherwise be unwilling to reciprocate by investing in a proportionate manner. A given country might object on grounds of international equity. Principles aside, they might view investing in planetary defense as impractical, given the risk that other countries will simply fail to contribute to the degree necessary for the shared enterprise to be successful and that their own contributions therefore will be wasted.

Monetary costs are not the only sorts of trade-offs involved in planetary defense. Numerous types of defense-related collaboration in space require potential trade-offs on national security. For example, reducing the overcrowding of satellites in earth's orbit may require some governments to disclose sensitive information about the locations of their satellites to other nations. This is made all the more sensitive by the fact that many of these satellites are themselves used for national security. Governments will understandably be reluctant to share this information, especially when they are not guaranteed to receive direct or tangible payoffs in national security.

An array of cognitive biases interferes with voters' and policymakers' ability to think critically about planetary defense. Perhaps the most pertinent example is known in the economics literature as future discounting: we have a tendency to overvalue gains and losses in the near future and undervalue those in the far future. Applying this concept to planetary defense, we run the risk of taking serious threats to our welfare less seriously the farther in the future they are. This is partly rational: politicians have a personal incentive in focusing on issues that they will be held accountable for during their tenures, let alone in their lifetimes. It is also partly the result of a cognitive bias: extensive empirical research suggests that we have a tendency to disproportionately discount the expected value of gains and losses in the distant future [3].

To make matters more difficult, the international community currently lacks a clear precedent for compelling or coordinating international cooperation in planetary defense. A number of space-related treaties exist, none of which directly address planetary defense. To the extent that they contain measures that might apply to planetary defense, they do not do so directly. The resulting ambiguity and uncertainty means that various methods of conduct would require more effort to justify. It also creates opportunities for selective interpretation and contributes to a general impression of tentativeness in the international community's commitment to and preparedness for planetary defense.

Existing laws leave a number of crucial aspects of planetary defense unaddressed, as will be discussed below. For example, existing international laws do not address the legal permissibility or procedure of using nuclear weapons against an NEO. What is the legal status of a coordinated use of nuclear weapons against an NEO, and how would such an action be categorized under existing international law? Even to the extent that using a nuclear weapon might not explicitly contravene international law, this would constitute a use of nuclear weapons unlike any in history, and any decision for or against it would benefit from some contextualization within the existing legal order. The lack of a clear legal framework makes it difficult to coordinate international conduct, as parties will be less confident taking risks without a well-defined standard by which to hold other parties accountable and ensure an effective allocation of resources.

3. Expanding our concept of planetary defense beyond NEOs

One example of the role that psychological factors play in planetary defense has to do with the very ways in which we conceptualize planetary defense. While most of the public discourse surrounding planetary defense has so far focused on NEOs, there are a number of other threats to global human welfare that require the international community's attention–each of which entails its own collective action problem and contributes to the general cooperative and competitive dynamics of planetary defense initiatives.

The lack of proportional attention given to these other topics is itself instructive. The way planetary difference is framed for the public (and by the public) exemplifies the sort of heuristics that we used to think about large-scale threats. Asteroids are large, tangible, and violent, and there is at least some historical precedent in popular culture for the sort of threat they pose. In contrast, anthropogenic climate change is diffuse, gradual, occurs over a large time scale, gradual, and, at least in some countries, ideologically charged.

Consider, for example, the idea of anthropogenic climate change as an ongoing and gradually increasing threat to global welfare. It may be appropriate to frame pro-environmental initiatives as a form of planetary defense, yet some parties might have ideological or normative attitudes that could prevent them from thinking realistically or practically about the planetary risks associated with those issues.

There's some irony in our focus on an NEO. The further we look into the future, the less certainty we have in assessing the likelihood of any particular NEO colliding with the earth. Other, more ordinary threats to planetary defense, especially those that are homegrown, have a higher degree of certainty. Yet we under-appreciate those risks, partly because they appear so mundane.

Even to the extent that we take NEOs seriously, we tend to take a defensive and reactive posture in our approach to planetary defense. Preventing a given collision event would require not just identifying the threat, but committing to extensive defensive initiatives many years in advance. Failing to take a proactive approach to planetary defense creates the risk that by the time we detect a pending near-earth threat, it will already be too late for any significant protective actions.

3.1. Satellite overcrowding

According to the U.S. Government Accountability Office, were almost 5,500 active satellites in orbit as of spring 2022, and one estimate predicts the launch of an additional 58,000 by 2030 [4]. Large constellations of satellites in low Earth orbit are the primary drivers of the increase.

The ongoing proliferation of satellites in orbit could increase a number of known risks to human activity on Earth. First, increased levels of atmospheric alumina released by damaged or reentered satellites has the potential to increase the harmful effects of solar radiation, contributing to ongoing environmental concerns. Second, increased movement of satellites in overlapping regions of Earth's orbital space increases the risk of collisions between satellites. Satellites are often concentrated in specific orbital regions that are considered especially valuable. Collisions between satellites is likely to result in widespread proliferation of space debris around the Earth. In fact, some have warned that a relatively small number of successive collisions could be enough to trigger a widespread chain reaction, causing an ever-increasing field of debris, a scenario known as the "Kessler syndrome." Simulations suggest that the early stages of the Kessler Syndrome have already begun in low earth orbit, but that this could be prevented from escalating through active removal of space debris [5].

As the number of satellites in Earth's orbit increases, so does the risk of space debris. As of 2019, there were estimated to be over 12,000 trackable pieces of debris of at least 10 centimeters in diameter in low-earth orbit; the U.S. Space Surveillance Network had tracked about 20,000 total pieces of debris in orbit [6]. As of 2021, there were 27,000 trackable pieces of debris [7]. Current estimates put the current number of smaller pieces of debris (larger than 1 centimeter in size) at nearly a million, while larger objects over 10 centimeters number in the thousands [8]. These numbers are only expected to increase. [9]. Once in orbit, and unless actively decommissioned, many of these satellites could remain in space for hundreds of years.

3.2. Weaponization of space

Cooperation regarding planetary defense is likely to be complicated further by the rise of national ambitions to expand into space. The last four years have seen an expansion of military branches for space-related activity across the world: the U.S. Space Force, the United Kingdom's Space Command, Japan's Space Operations Squadron, and the development of the French Air Force into the Air and Space Force, among others.

As space-related technology continues to advance, international competition over the ability to mine space minerals could intensify existing international conflicts on Earth, contributing to general tensions in global politics and creating added friction for international cooperation in planetary defense.

In particular, the prospect of an arms race in space contributes to the risks posed by the overcrowding of satellites. Extensive launches of government satellites would contribute to the number of satellites in Earth's orbit and increase the total risk of collisions and resulting space debris. Intentional attacks on competing countries' space infrastructure would only do further damage.

There is also the potential for rapid military development in space to adversely affect Earth's environment. The development of military space capacities would contribute to the risks already posed by the increased proliferation of public and private-sector satellites. This could include ozone damage and wide-ranging effects of black carbon emissions [10], as well as unknown effects on the ocean environment due to extensive rocket stages containing unspent hydrazine fuels [11].

In addition, the general increase in competition between nations, combined with greater arms capabilities, could increase the likelihood of deliberate or accidental uses of space-based weapons on targets on

Earth–in effect, broadening the general possibilities for destructive military conflict. Individual countries might in some cases be unwilling to share confidential information regarding their military capabilities, which could lead either to a general underappreciation of the extent of the problem, or to greater widespread distrust among competing countries.

The same sorts of high-energy weapons that would be used against an NEO have been contemplated for use in warfare. Specifically, countries such as the U.S., Russia, China, India, and Israel have experimented with both kinetic-energy and directed-energy weapons capable of destroying satellites. The primary danger of ASAT for planetary defense purposes is that destroying satellites, especially by means of a kinetic-energy weapon, would result in space debris as a side effect of the weapon's collision with the target satellite. Such anti-satellite ("ASAT") systems have been tested in a handful of infamous cases, sometimes causing new space debris to enter the Earth's orbit [12]. In 2007, China deployed an ASAT system to destroy an aging Chinese weather satellite, producing three thousand pieces of trackable debris (approximately 17% of all human-caused space debris in orbit as of that time). The resulting debris is expected to remain in orbit for decades or centuries [13].

Countries have been less than forthcoming about their experiments with ASAT technology. In 2013 and 2020, China conducted a set of tests that they described as missile defense tests, though the overlap with ASAT testing is hard to ignore. There is substantial overlap between ASAT systems and more conventional anti-ballistic weaponry. The result is that, in order to effectively regulate or prevent the use of ASAT technology, countries would have to be willing to limit other forms of weaponry not explicitly related to space [13].

International efforts to limit the expansion of weapons into space, especially anti-satellite testing, have stalled for decades. Multiple rounds of bilateral negotiations were undertaken in 1978, 1979, and 1985, but ultimately did not succeed. Many countries (including Russia, China, and EU member states) have proposed treaties and codes of conduct to prohibit the weaponization of space, but all such proposals have thus far been met with controversy and firmly opposed [13].

U.S. officials have expressed concern about joining international agreements that would limit their activity in space and have stated their commitment to maintaining space-related military systems for self-defense purposes [14]. The U.S. has been particularly enthusiastic about the prospect of achieving military dominance in space. Many within the U.S. military believe that warfare in space is inevitable, precisely because the opportunities for military power are too attractive for any spacefaring country to resist (a prisoner's dilemma). Indeed, Chinese government officials have publicly stated their intent to develop weapons with "the ability to strike U.S. satellites," claiming that their goal is merely to do so as a means of deterrence providing "strategic protection to Chinese satellites" [15].

3.3. Increased international conflict

It would not be entirely irrelevant to planetary defense to point out the general risks to planetary welfare posed by extensive, high-tech international military conflict. If our goal is to protect human life on Earth from large-scale destruction, the fact that some of the more probable threats are of our own making should not be a source of discouragement. All the more so when the technologies threatening to inflict such destruction on earth are being adapted to orbital use—and overlap substantially with the technology that would be used to defend the earth against NEOs. A variety of related goals are currently being pursued in the U.N., with possible treaties being considered for topics such as expansion on the INF treaty, decreased production of fissile materials for use in nuclear weapons, the creation of "nuclear weapons free zones," and the total abolition of nuclear weapons worldwide [16].

It's tempting to say that the solution is to require regulation, but because the weaponization of space reflects, and would be a continuation of, international conflicts on Earth, it is unclear that any nation would be willing to agree to such regulations. This is especially the case if some of the countries that would be submitting themselves to regulation distrust the movies of other countries. For example, some nations have objected that the U.S. has already equipped itself with space weaponry, and that a bill preventing other countries from doing the same would therefore be to its advantage. Countries will only accept regulation of space weaponry if they are confident that other countries will abide by those regulations. In this case, the risks of betrayal might be too high; a critical number of countries have a rational interest not only in refusing to accept such a treaty (refusing to cooperate), but even in increasing their military expansion into space (preemptive mutual defection).

All the more so because satellites used for national security purposes of any kind are contentious, meaning that countries have an interest in revealing as little about them as possible. Relatedly, some countries might object to certain non-violent uses of satellite technology by other countries that run contrary to their interests. Many nations use satellites as "national technical means of verification" (NTM) to monitor compliance with anti-nuclear and other international treaties, such as the 1996 Comprehensive Test Ban Treaty (CTBT). It could be politically advantageous for one country to object that international surveillance of this sort entails the intrusive collection of confidential information by one country about another for reasons related to military intelligence. Given that the U.S. is one of the main providers and facilitators of NTM satellites, some countries might want to establish their own NTM systems to decrease the United States' dominance over space-related intelligence.

Imposing effective prohibitions on space weaponry would require more serious discussion between nations as to the state of their military activities in space, but governments have an obvious interest in preserving the secrecy of their weapons development programs. The risk is that too many parties will prioritize their security concerns—if not out of ambition, at least to protect themselves against other nations whose motives are unknown—and that too little information will be provided to result in substantive reforms.

4. Legal challenges for international cooperation

Effective cooperation in planetary defense requires an objective system for promoting cooperation, drawing on principles with widespread legitimacy. This ordinarily would take the form of a legal regime. Yet the lack of an established and well-tested legal regime for outer space, especially regarding military activity, weakens the grounds for international trust. While laws such as the Outer Space Treaty exist on paper, the fact that they have never been enforced in any serious capacity—and have yet to be developed into a comprehensive framework—threatens the perceived legitimacy of existing rules for national and international space-related activity.

The most striking weakness of the Outer Space Treaty is its lack of enforceability: the provisions of the treaty are non-binding and are not legally enforceable against state parties. While there might be some benefits to a non-binding legal agreement (as argued below), the lack of clarity surrounding the law of planetary defense prevents pastries from being able to coordinate their behavior effectively to begin with. In order for an unenforceable treaty to succeed, it must at least have the benefit of setting precise standards of conduct.

The legal regime for space consists of three treaties in addition to the OST: the 1968 Rescue and Return Agreement protects astronauts and space vehicles; the 1972 Liability Convention establishes tort-law standards of liability for damage on earth caused by a space objects under a given country's control; the 1975 Registration Convention requires launching states to publish information regarding its space objects. None of these standards directly address military activity in space or the need for international cooperation in planetary defense.

Article VI of the 1967 Outer Space Treaty states that "States shall be responsible for damage or injury caused by the launching or attempted launching into outer space of objects," but it does not specify a legal process with which to adjudicate or determine damages. Moreover, the Treaty does not explicitly address compensation in the event of coordinated international activity. This could make countries ambivalent about agreeing to contribute to planetary defense measures that would require them to accept a risk of collateral harm. For example, pulverizing an NEO could cause some fragments of the NEO to hit the Earth. The countries that possess the impacted territories might seek compensation from the international community for any resulting damage, especially if that country had contributed funds or other resources to the project resulting in the pulverization. Without more robust assurance that participating parties will be insured fairly for losses undertaken in helping to avert an NEO, prospective parties will be unnecessarily hesitant to agree to such measures.

Moreover, there are crucial gaps in the existing legal framework, which are ripe for exploitation and selective interpretation by self-interested parties. As one poignant example, Article XI of the Outer Space Treaty bans "weapons of mass destruction" in space, but the treaty does not forbid launching ballistic missiles, which could be armed with WMD warheads.

One legal scholar has observed that the OST's provisions promoting peaceful space-related activity "are vital and virtually universally accepted, but in reality, they do not much inhibit practical satellite weapons programs or constrain various countries' military aspirations in space" [13]. The OST's Article IV bans the testing of weapons on celestial bodies in particular, leaving open the possibility of weapons testing in earth's orbit. Article IV bans the placement of nuclear weapons and other weapons of mass destruction in Earth's orbit or elsewhere in space, but it contains no restrictions on conventional weapons. Moreover, Article IV forbids "the establishment of military bases, installations and fortifications, the testing of any type of weapons and the conduct of military maneuvers on celestial bodies." These prohibitions do not apply to military activities in other areas of space, such as weapons tests in orbit around the Earth. To the extent that one could interpret the OST in such a manner, decades of established practice by NATO member states indicates that the international government chooses to view space as eligible for military operations [17].

One could argue that military activity in space is implicitly outlawed by Article III of the OST, which provides that space-related activities are subject to general principles of international law (including the prohibition on the threat or use of force in Article 2(4) of the UN Charter). However, in-space weapons tests are not directed at individual states and do not occur within the sovereign territory of any particular state, meaning that they are unlikely to qualify as unjustified uses or threats of force.

The lack of precedent or explicit guidance in interpreting the language of the OST could be exploited by parties looking to justify self-interested conduct. Article IV imposes only a requirement that countries consult one another before engaging in activities with the potential to cause “harmful interference” for the peaceful exploration of space by all nations. Such a requirement leaves it to the acting country to decide whether the activity in question counts as posing a threat to other countries (consider, for example, that Russia has argued that “harmful interference” is difficult to measure objectively) [18]. States rarely consult each other before engaging in potentially destructive space-related activities—no consultation has been sought by the U.S. when destroying its own satellites, or by Russia, China, or India when conducting anti-satellite weapons tests. Indeed, one could make the plausible argument that because any spacefaring event can result in debris, even countries committed to following best practices under U.N. law could pose a risk to the orbital commons simply by engaging in ordinary spacefaring activity.

Even if these sorts of actions do not technically fall under the scope of the OST’s prohibitions—indeed, regardless of their legal status—widespread unease at the proliferation of space-related weapons tests and related military activity could erode trust between nations. This runs the risk of (1) making countries less willing to accept cooperation risks for collective action in other, conventional areas of planetary defense, and (2) contributing directly to a tragedy of the commons in orbital space, threatening to impose a range of dangers on those on Earth and to interfere with planetary defense technologies.

5. Promoting international cooperation in planetary defense

Overcoming the overlapping collective action problems of planetary defense will require a multilateral approach to resolving cooperative tensions and uncertainty between interacting parties. Some of these solutions might involve traditional strategies for strengthening norms and building trust; others might draw on psychological principles, such as those from the behavioral economics literature, to improve the ways in which parties view their interests in relation to planetary defense.

5.1. Managing the commons

Ostrom’s 1990 seminal study of collective action problems identifies several key principles that can be applied to planetary defense. First, in order for parties to be willing to act more responsibly in maintaining a common resource, the commons must have clearly defined boundaries [19]. When it comes to NEOs, this might be as simple as emphasizing the shared vulnerability of all countries to an asteroid impact event. Other areas currently receiving less attention might require more emphasis. This means, for example, delineating the scope of permitted activities in orbital space, encouraging parties to abide by common standards, which starts with drawing attention to the need for a clear and safe orbital space around the Earth.

Second, participatory decision making also encourages widespread compliance [19], as parties feel personally invested in and responsible for initiatives that they helped create and that they view as reflections of their values. This means encouraging a large number of parties throughout the international community to participate in drafting new measures toward planetary defense. Giving nominal opportunity for participation to countries that might be more likely to act selfishly might also provide those countries with face-saving opportunities to boost their credibility and standing on the international stage, offering them reputational gains in exchange for compliance with common standards of conduct.

Third, sanctions should be proportional to the harm in question [19]. This can include using informal penalties, such as reputational consequences, rather than imposing penalties that parties might consider unduly severe. The ideal strategy for imposing sanctions would be to establish sanctions based on new agreements that parties enter voluntarily.

Finally, management of the commons works best when integrated into large networks of cooperation [19]. Establishing ties between the existing planetary defense initiatives and a wide range of international agencies will help to create a shared sense of responsibility and wide visibility for planetary defense. Indeed, one practical advantage of emphasizing the overlap between planetary defense and more conventional international policy goals, such as environmental reform, is the potential for coalition building and integration of existing administrative resources.

5.2. Soft law

Another possible strategy would be to explore the possibility of using “soft law” mechanisms to set common standards and encourage widespread compliance with those standards. The concept of soft law involves nonbinding guidance with a legal or regulatory structure–in essence, laws without legal effect [20]. The use of soft is already used elsewhere in international law [21] and is being explored in other contexts involving the implementation of new technologies with uncertain legal implications [22]. In order to make nonbinding international rules effective, such rules must set explicit standards of conduct.

5.3. Pre-commitment devices

One of the best-known strategies in the economic literature for altering behavior is the use of pre-commitment devices, whereby parties commit themselves to measures that limit their future selves' capacity for adverse behavior [23]. One can view international treaties and related agreements as pre-commitment devices: countries hold themselves (as well as others) accountable in the future to commonly accepted standards of conduct. In the context of planetary defense, the use of pre-commitment devices could come in the form of international agreements to meet any of a variety of benchmarks for collective investment in planetary defense. These could include, as examples, allocation of funds toward planetary defense operations by national or international agencies; compliance with international regulations promoting removal of space debris; compliance with international restrictions on the total number of annual authorized launches of private satellites; or sharing information with international agencies to coordinate the safe navigation of satellites throughout Earth's orbit.

Such measures are more likely to succeed when consequences are attached. This would entail penalties to be imposed on parties that fail to meet certain accepted benchmarks for planetary defense initiatives. These could take the form of "hard" penalties, such as fines or other tangible losses, or "soft" penalties such as reputational losses. Hard penalties are more likely to motivate parties that are already committed, but parties might be less inclined to subject themselves to such penalties in the first place; soft penalties have a lower cost of entry and might therefore be more effective at encouraging widespread buy-in.

5.4. Opt-out policies

A related strategy might be to employ the use of defaults, a classic principle of behavioral public policy and choice architecture. Rather than imposing mandates that parties might view as coercive, the international community might benefit from implementing treaties and agreements that give parties the option not to participate in certain respects. Opt-out policies have proven useful across a range of policy domains, including organ donation and retirement savings [24]. This approach would harness reputational costs as a form of soft power: encourage parties to reap the benefits of publicly joining programs with a good cause, while putting pressure on them to contribute to those programs at a later time in order to avoid the shame of falling short of the common standard.

The gains in autonomy for bound parties might give planetary defense initiatives greater perceived legitimacy. They might prove especially useful for gathering support for NEO-related research and development, since many might continue to view the risks posed by NEOs as uncertain. Parties might be more willing to join a planetary defense agreement if they maintain the ability to scale down their participation as circumstances change and new information comes to light. Although parties would have the nominal option not to participate (or to stop participating) in a given international agreement, they might draw unwanted attention to themselves and incur substantial reputational costs by doing so. Opt-out policies would thus offer a possible mechanism for encouraging parties to join agreements with soft penalties.

5.5. Framing

In order to more effectively pursue planetary defense, we must reframe our conception of planetary defense, including the sorts of risks that do and do not fall within its scope. Certain state actors might object to including such politically charged topics as environmental reform and denuclearization under planetary defense, but it is hard to deny the relevance of climate change and nuclear warfare (among other threats) to human survival, including their relevance to our ability to maintain an effective readiness against NEOs.

At the risk of stating the obvious, the most pervasive strategy for encouraging planetary defense is to increase public support for planetary defense. Especially in democratic societies, it is crucial to promote the importance of planetary defense initiatives (including international cooperation in pursuing those initiatives) so that members of the public will put pressure on their elected representatives, and on other government officials, to prioritize these issues.

As for generating public and political support for planetary defense initiatives, perhaps the most effective strategy would be to frame the issue in terms that are accessible and that appeal to widely held values and interests. While regulators should attempt to provide the public with a more accurate appraisal of the probabilities and risk magnitudes of planetary threats, it is also important to recognize that such efforts are going up against a set of deeply entrenched cognitive biases that may not be responsive to data alone.

The ideal approach to public messaging regarding planetary defense would be to implement multiple styles of framing. In all cases, it would be valuable to frame these issues in terms that resonate with the values held by a wide range of stakeholders. In some cases, it might be valuable to focus on using terms that are ideologically neutral. In other cases, such as when promoting regulation and other solutions that might entail politically charged tradeoffs, it might be preferable to focus on reframing those tradeoffs as investments in values held by the affected groups [25]. Conservatives in the U.S.

are likely to respond favorably to messaging that emphasizes the opportunity for private industry and military technology to be used. For example, when discussing satellite overcrowding, it might be useful to promote regulation of the satellite industry by emphasizing the adverse implications of satellite malfunctions for telecommunications and large-scale economic functionality on Earth, as well as the risks posed by space debris for the burgeoning commercial spaceflight industry. Progressives are likely to respond favorably to messaging that emphasizes the connections between planetary defense and environmentalism; this could include highlighting the possible downstream effects of satellite overcrowding on climate change in creating a greenhouse effect.

Another essential strategy is to create a new legal framework for (and reinforce existing laws surrounding international cooperation toward) planetary defense. The ongoing increase in public interest in planetary defense creates an opportunity for new laws providing more robust international guidance and clearer standards of enforcement. Rather than simply proposing new legal rules or standards as elaborations on existing agreements, it might be beneficial to introduce those proposals under an entirely new treaty. More broadly, there are reasons to consider framing legal developments related to planetary defense, to the greatest extent possible, in terms of entirely new laws. Extensive psychological research points to the power of novelty and recency in directing people's attention [26]. Enacting new agreements explicitly devoted to planetary defense issues might draw the public attention by way of a novelty bias, framing the global commitment to planetary defense as a new moment in international and environmental law. This could increase the salience of any new legal proposals in the public and political arenas, which may contribute to increased public awareness of the underlying issues and widespread support for planetary defense initiatives.

6. Conclusion: Fostering a planetary perspective

International cooperation is crucial for addressing the global threat posed by NEOs and other planetary threats, as planetary defense measures require a coordinated and collaborative effort among nations in order to succeed. Promoting international cooperation will require a feedback loop consisting of transparent communication, confidence-building measures, and robust international organizations and networks that facilitate collaboration and coordination among nations. Understanding and addressing the cognitive dimensions of risk assessment can also help policymakers to promote more effective cooperation in planetary defense initiatives and enhance the global response to planetary threats (including those of our own making).

Arguably the most fundamental problem for promoting plenary defense is also the most elusive. The current emphasis on local and national interests to the exclusion of international needs reflects what some might consider a limited perspective on global issues. Ultimately, the success of more targeted policy strategies for promoting international cooperation in planetary defense will depend on the degree to which the global community shares a basic sense of appreciation for these issues.

One of the most powerful cultural messages in the last several decades is the concept of our home world as a small, fragile planet–a "pale blue dot" suspended in the endless void of space. This is largely due to the popularization of photographs taken of Earth from space, which portray our familiar home from a radically unfamiliar perspective. Indeed, many astronauts describe the experience of viewing the Earth from space as one of the most profound and personally influential moments of their lives–an experience known as the "overview effect" [27]. The overview effect seems to entail a deep psychological shift of perspective, causing astronauts to feel a deepened appreciation of their relationship to humanity and sense of responsibility to the planet itself [28].

One wonders whether the power of the overview effect points the way to a subtler, more pervasive type of solution. Perhaps, ultimately, the most important long-term strategy for fostering public support for planetary defense can be found in the rise of a "global perspective" on human affairs: fostering a sense of global community in which citizens of countries across the globe prioritize issues of universal human concern—and promote transnational cooperation in solving those issues.

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