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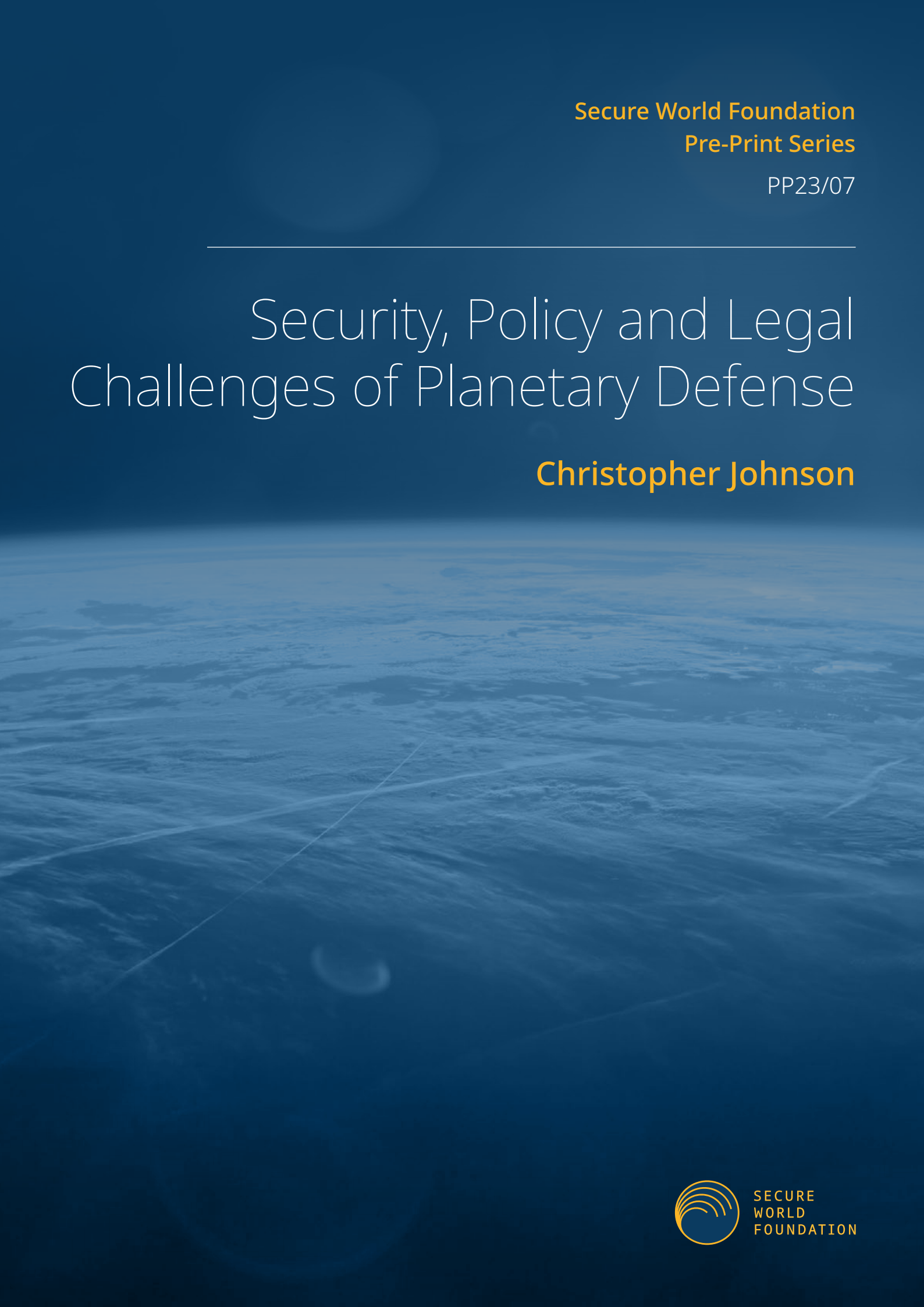
Security, Policy and Legal Challenges of Planetary Defense

Christopher Johnson



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About Secure World Foundation

The Secure World Foundation strives to be a trusted and objective source of leadership and information on space security, sustainability, and the use of space for the benefit of Earth. We use a global and pragmatic lens to study and evaluate proposed solutions to improve the governance of outer space. While recognizing the complexities of the international political environment, SWF works to encourage and build relationships with all willing stakeholders in space activities, including government, commercial, military, civil society, and academic actors. Central to this approach is increasing knowledge about the space environment and the need to maintain its stability, promoting international cooperation and dialogue, and helping all space actors realize the benefits that space technologies and capabilities can provide.

About Christopher Johnson

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Security, Policy and Legal Challenges of Planetary Defense

Christopher Daniel Johnson

Summary and Keywords

Summary:

Potentially Hazardous Near-Earth Objects (NEOs), including both asteroids and comets, pose serious risks to human and environmental security on Earth. International arrangements such as the International Asteroid Warning Network (IAWN) and the Space Mission Planning and Advisory Group (SMPAG) exist as coordinating mechanisms to detect, characterise, and assess NEO threats, and to discuss and share information on possible ground and space-based threat responses and mitigation measures. However, the international political and legal environment is not currently adequate to deal with NEO threats. While some elements of international law, including space law, provide broad guidelines, necessary clarity is lacking. The international legal and political order does not have in place adequate safeguards, mechanisms for action, the clear delineation of roles, rights, and responsibilities at the international level to respond to a NEO threat. Additionally, a number of stressors on rational decision making exist and would degrade the quality of NEO threat responses. Stressors on the quality of decisions and actions in response to a NEO threat including the incentive to wait for further data about the NEO, a conflicting incentive to take immediate action and bold steps so as to immediately satisfy constituents and to feel some amount of control over the situation. Public distrust, misinformation, disinformation, and conspiracies are all also likely, and will degrade public reactions and stakeholder decisions. A number of steps can be taken now, while the NEO threat remains hypothetical yet likely. These steps are warranted so as to assure the best possible response when a real, actual NEO threat emerges.

Keywords:

asteroid, comet, international law, militarization, Near Earth Object, NEO, planetary defense, space law, outer space, United Nations, weaponization

1 Introduction

Cataclysmic asteroid strikes have jeopardised life on Earth before, and will do so again. These naturally-occurring cosmic hazards are worryingly difficult for societies to collectively anticipate and plan responses for. This is perhaps because they are natural phenomena so devastating they seem beyond humanity's power to respond to effectively. Like other naturally-occurring disasters—whether earthquakes, volcanic eruptions, tornados, cyclones, tsunamis, droughts or plagues—one might assume that humanity is simply helpless in the face of these threats. According to this way of thinking, we should just take our chances and suffer what we must: perhaps to perish, or perhaps to survive.

Others believe that coordination and preparation against an asteroid or comet strike is possible—and even necessary—if we want our civilization to survive. Planetary defense is the activity and actions to predict and mitigate a potential impact by an asteroid or comet on the Earth.[i] Beyond technical challenges of threat detection, prediction, and response, planetary defense against Near Earth Objects[ii] (NEOs) involves intimidatingly large and uncertain social, cultural, and geopolitical challenges. Nevertheless, effective planetary defense requires that we rationally and thoroughly understand and address each element of a NEO threat, the challenges of our response

to it, and that we take effective preparation steps for the day the potential NEO threat becomes real.

The idea of local, regional, or even global devastation from a natural (but rare and uncertain) phenomenon, whether suffered collectively or individually by a state or group of states, obviously gives rise to social and political tensions and the possibility of slow and uncoordinated responses between actors, including national emergency planners, political leaders, legislative bodies, national space agencies, and national security and military structures. There is also the possibility of uncoordinated international responses between national governments. Geopolitically, the risks of misperceptions and miscommunications in NEO response forecast international tensions between states.

This article is an attempt to think through the geopolitical and security implications of planetary defense, including why governments and societies face challenges in planning, and in acting when the threat is real and an Earthstrike is likely and imminent. It will offer predictions on how governments and populaces might react to concrete NEO threats. It will then go through some hypothetical scenarios to show the relevant and applicable laws which characterise these scenarios, and how decision makers might and ought to react in the face of NEO threats, including actions that can be taken in the present, before a credible NEO threat is discovered.

2 The Threats from Hazardous Near-Earth Objects

The security implications from hazardous NEOs stem from the fact that the damage they threaten can be indiscriminate, widespread, severe, and largely unpredictable. The damage and destruction threatened by NEOs depends on a variety of factors, including their composition and internal integrity, their speed, their incoming angle of attack as they enter the Earth's atmosphere, and where they strike (land or oceans; in populated areas or not).

2.1 Airblasts

As a general rule, stony objects smaller than 30 metres in size are unlikely to cause any ground damage and will break up in the atmosphere and become fireballs and meteors. Stony objects between 30 metres and 100 metres in size will also not impact the Earth, but their breakup in the atmosphere will result in airblasts causing significant damage on the surface of the Earth. At around 100 kilometres altitude, an incoming NEO will begin to be subjected to air resistance, which will place more pressure on the front of the NEO than at the rear of the NEO. This will cause the NEO to flatten, or "pancake", and if the atmospheric pressure is greater than the internal strength of material comprising the NEO, it will disintegrate and its kinetic energy will be translated into a small volume of strongly heated air which will quickly expand into an explosion, or airburst, that generates a powerful pressure pulse followed by tremendous winds. Airblasts can produce far more destructive force than an object which strikes the surface (which is why bombs are designed to explode above their targets, rather than on the ground itself).

The Tunguska Event on 30 June 1908 is one such example of an incoming NEO which broke up in the atmosphere to produce an airburst with tremendous destructive force, and leaving only microscopic remnants of the NEO. It is believed that the Tunguska event was the result of a small NEO of around 40 metres in diameter, creating an airburst of between 3 and 5 megatons of energy. This air blast levelled millions of trees over 2,200 square kilometres. NEOs of this size are expected to strike the Earth every few hundred years.

2.2 Earthstrike

Stony objects larger than 100 metres will likely make their way to the ground (or ocean) with potentially massive impacts as a result.[iii] A ground strike and its attendant blast wave would result in strong and destructive winds, a heat pulse, and seismic shaking. Larger impacts would

also cause fires from the strong hot winds and ejecta from the impact, as well as dust and soot entering the atmosphere to cause regional or even global weather impacts, as well as acid rain. Damage to the Earth's atmosphere may also result in a kind of nuclear winter, where plant photosynthesis is degraded or disrupted for long stretches of time. The blast wave resulting from the impact would also create an impact craters the likes of which are visible from previous asteroid strikes on the Earth, and also evident on other celestial bodies.

NEO expert Donald Yeomans explains the result of larger impactors:

> An impactor larger than a few kilometers would cause a global catastrophe because of a brief initial heating of the Earth's atmosphere and surface followed by an extended period of cooling and related darkness. Much of the impact ejecta would shoot back up the asteroid's incoming flight path in a ballistic fashion and exit the Earth's atmosphere along this path of least resistance. It would then reenter the atmosphere, heat to incandescence, and cause atmospheric heating and worldwide firestorms. The firestorms would then create enormous amounts of soot in the atmosphere. The combination of eject dust and firestorm soot could increase the opacity of the Earth's atmosphere for weeks at a time, shut down much of the sunlight and photosynthesis, and kill the plants as well as the creatures that depend upon these plants for food.[iv]

2.3 The Torino Scale

The Torino Scale, adopted by the International Astronomical Union (IAU) in 1999, categorises the impact risk from NEOs on a scale of zero to 10, with zero being least severe and 10 most severe.[v] A zero on the Torino scale represents a NEO with a probability of collision as zero or so low as to be considered zero. A zero applies to small bodies such as meteors that burn up in the atmosphere, as well as rare Earth falls of meteorites, which seldom cause damage. A new and routine discovery of a NEO with an extremely low risk of collision is initially given a 1 on the Torino scale, and subsequent observations likely reassign it to level zero.

Moving up the Torino scale reflects *increases in the probability* of an Earthstrike, as well as *increases in the severity* of the damage threatened. A 3 on the Torino scale reflects an NEO which threatens **local destruction** and with an impact probability of greater than 1%. A 4 on the Torino scale is identical to a 3, but threatening **regional devastation**. A 5 on the Torino scale represents a **greater (but still uncertain) probability** of impact, and with the threat of **regional devastation**, meriting attention if a collision is less than 10 years away.

The Torino Scale		
No Hazard (White Zone)	**0**	The likelihood of a collision is zero, or is so low as to be effectively zero. Also applies to small objects such as meteors and bodies that burn up in the atmosphere as well as infrequent meteorite falls that rarely cause damage.
Normal (Green Zone)	**1**	A routine discovery in which a pass near the Earth is predicted that poses no unusual level of danger. Current calculations show the chance of collision is extremely unlikely with no cause for public attention or public concern. New telescopic observations very likely will lead to re-assignment to Level 0.
Meriting Attention by Astronomers (Yellow Zone)	**2**	A discovery, which may become routine with expanded searches, of an object making a somewhat close but not highly unusual pass near the Earth. While meriting attention by astronomers, there is no cause for public attention or public concern as an actual collision is very unlikely. New telescopic observations very likely will lead to re-assignment to Level 0.

	3	A close encounter, meriting attention by astronomers. Current calculations give a 1% or greater chance of collision capable of localized destruction. Most likely, new telescopic observations will lead to re-assignment to Level 0. Attention by public and by public officials is merited if the encounter is less than a decade away.
	4	A close encounter, meriting attention by astronomers. Current calculations give a 1% or greater chance of collision capable of regional devastation. Most likely, new telescopic observations will lead to re-assignment to Level 0. Attention by public and by public officials is merited if the encounter is less than a decade away.
Threatening (Orange Zone)	**5**	A close encounter posing a serious, but still uncertain threat of regional devastation. Critical attention by astronomers is needed to determine conclusively whether or not a collision will occur. If the encounter is less than a decade away, governmental contingency planning may be warranted.
	6	A close encounter by a large object posing a serious but still uncertain threat of a global catastrophe. Critical attention by astronomers is needed to determine conclusively whether or not a collision will occur. If the encounter is less than three decades away, governmental contingency planning may be warranted.
	7	A very close encounter by a large object, which if occurring this century, poses an unprecedented but still uncertain threat of a global catastrophe. For such a threat in this century, international contingency planning is warranted, especially to determine urgently and conclusively whether or not a collision will occur.
Certain Collisions (Red Zone)	**8**	A collision is certain, capable of causing localized destruction for an impact over land or possibly a tsunami if close offshore. Such events occur on average between once per 50 years and once per several 1000 years.
	9	A collision is certain, capable of causing unprecedented regional devastation for a land impact or the threat of a major tsunami for an ocean impact. Such events occur on average between once per 10,000 years and once per 100,000 years.
	10	A collision is certain, capable of causing global climatic catastrophe that may threaten the future of civilization as we know it, whether impacting land or ocean. Such events occur on average once per 100,000 years, or less often.

Table 1: *The Torino Scale*. Developed by the International Astronomical Union (IAU), the Torino Scale categorizes the terrestrial risk posed by NEOs. Source: Center for Near Earth Object Studies, Torino Impact Hazard Scale, https://cneos.jpl.nasa.gov/sentry/torino_scale.html

Further up the Torino scale are more threatening risks: threatening because their probability increases, and because the damage threatened increases (from local to regional to worldwide catastrophes). An 8 on the Torino scale is a risk that is certain to strike the Earth with destruction threatened on a local scale, while a 9 threatens destruction on a regional scale, and a 10 threatens destruction on a global scale.

Regarding the actions required by the Torino scale, levels 2, 3, and 4 require **special attention and possible plans of action**. Levels 5, 6 and 7 are to be **considered alarming and require preparation for action**. Finally, levels 8, 9, and 10 represent **certain collisions and require definitive action**. It must be understood that from the time of detection, subsequent observations of the NEO may cause its place on the Torino scale to change.

The Torino scale was developed to facilitate communication and understanding with the public and with decision makers. For the purposes of understanding the security implications of NEO risks, the three main elements informing a NEO's Torino level (probability, severity, and imminence) each influence the destabilising and unpredictable nature of NEO strikes, and their potential for national political, social, cultural, and geopolitical disruptions.

2.4 Differentiated Risk Exposure

States are exposed to different levels of risk from hazardous NEOs. As illustrated in various NEO impact scenarios (including those used at the annual Planetary Defense Conference[vi]), "strike corridors" (also called "risk corridors") of a NEO likely cross over multiple countries.

Smaller countries with less territorial surface area have less exposure to being struck than those states with vast territories. This means that some states have smaller chances than others, and thus perhaps they have a lesser incentive or rationale to participate in planetary defense as compared to larger states. Additionally, the Earth's surface area is approximately 70% water, so states with coastlines are exposed to the risk of tsunamis resulting from a NEO strike on the oceans.

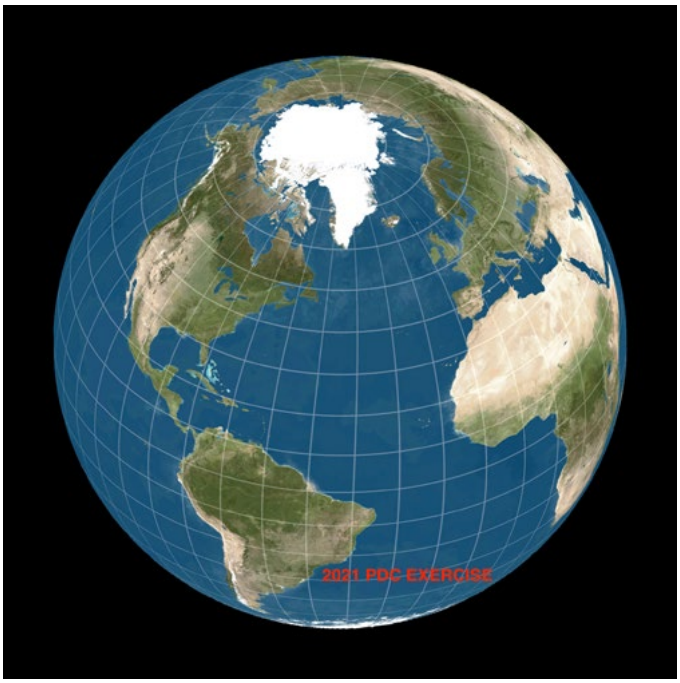

Figure 1: *Projected Zone of Probable Impacts in the 2021 PDC Exercise*
Source: Center for Near Object Studies, Planetary Defense Conference Exercise - 2021, https://cneos.jpl.nasa.gov/pd/cs/pdc21/

Figure 1: *Projected Zone of Probable Impacts in the 2021 PDC Exercise* is an image of the projected regions of the Earth as viewed from the oncoming asteroid.[vii] The image was used in the 2021 Planetary Defense Conference exercise in order to simulate the possible impact locations in their hypothetical exercise, and reflect the view from an incoming asteroid facing the Earth. It is a slightly flattened image of the Earth, and locations at the edge (while over the horizon) remain at risk, as gravity would bend NEO trajectories towards impact there. Countries not in this image (such as Australia, India, Indonesia) are not at risk in this hypothetical NEO scenario.

This image illustrates the fact that initial projects of an NEO strike could show a strike projection with a certain amount of vagueness, and that a long list of countries is endangered. In a real scenario, greater specificity of the expected strike location might be impossible to know, or impossible to know far enough in advance to shape reactions and plans. Planetary defense planners must reflect on this image and ask: if this is the greatest degree of specificity possible beforehand, how best to effectively execute planetary defense planning?

3 Relevant Entities in Planetary Defense

A number of existing entities and organisations are already involved in planetary defense, including groups at the international political level, at the national level, and within the international scientific community.

3.1 The International Astronomical Union (IAU) Minor Planet Center

The Minor Planet Center, hosted by the Harvard and Smithsonian Center for Astrophysics in Cambridge, Massachusetts, acts as a clearing house for observations and data about small celestial bodies in our solar system.[viii] It is responsible for the identification, designation, and orbit computation of minor planets such as asteroids and comets, and its tasks include maintaining the master files of observations and orbits, and announcing discoveries. When a new NEO is discovered, an astronomer notifies the Minor Planet Center, which will then request additional observations from its network of observatories worldwide to confirm and refine their initial observation. In this manner, a fuller and more detailed understanding of NEOs can be developed. As of 2023, the Minor Planet Center and its network have discovered or confirmed the discovery of over 1.2 million minor planets, comprising over 32,000 NEOs and over 4,500 comets. The Minor Planet Center also has a dedicated web portal on the coordination and dissemination of NEOs, including potentially hazardous NEOs.[ix]

3.2 The International Asteroid Warning Network (IAWN)

The International Asteroid Warning Network (IAWN) was established in 2013 by United Nations General Assembly Resolution 68/75, upon the recommendation of the United Nations Committee on the Peaceful Uses of Outer Space (COPUOS).[x] Functioning as an international response to a potential NEO impact threat, the IAWN is an international group of organisations involved in detecting, tracking, and characterising NEOs.[xi] The IAWN is further tasked with developing a strategy, using well-defined communication plans and protocols, to assist governments in the analysis of asteroid impact consequences and in the planning of mitigation responses.

It should be stressed that the IAWN receives no funding from the United Nations, and is a network of organisations each searching for asteroids, determining their threat to the Earth, and communicating with the public and with decision makers regarding these threats. To that end, they have significantly improved the sharing of information between actors regarding NEO threats. As of 2023, there are over 40 signatories to the IAWN Statement of Intent.[xii]

3.3 The Space Mission Planning Advisory Group (SMPAG)

Created at the same time as the IAWN, the Space Mission Planning Advisory Group (SMPAG) acts complementary to the IAWN and is endorsed by the United Nations.[xiii] Its task is to prepare for an international response to a threat by a near-Earth object through the exchange of information, development of options for collaborative research and mission opportunities, and to conduct NEO threat mitigation planning activities.[xiv] The SMPAG currently comprises twenty-six member organisations, including national space agencies, several observer organisations, and the IAWN as an *ex-officio* member.[xv]

The scope of the SMPAG's activity includes a variety of activities that it might undertake. These include research and recommendations dealing with planetary defense reference missions, technology roadmaps, and collaborative research. Another area deals with communications and exchanges of information between SMPAG members on planetary defense topics, including opportunities for collaboration and national planetary defense activities. Another area for SMPAG activities is on policy and legal issues. Here, the SMPAG may "[i]dentify for possible detailed review within appropriate forums any legal and policy issues (e.g., liabilities) that may arise in undertaking NEO mitigation actions or selecting any likely mitigation options."[xvi]

The SMPAG can choose to engage in planetary defense planning activities. Specifically, it may[xvii]

a. Recommend operational responsibilities for a space-based NEO mitigation campaign.

b. Work in coordination with the relevant actors potentially involved in the implementation of the threat response.

c. In case of a credible threat, recommend viable concepts for a possible mitigation campaign and directly inform those governments that would coordinate and fund space mission activities and request that they in turn inform UN COPUOS, via the UN Office for Outer Space Affairs if necessary.

It must be noted that participation in the SMPAG is voluntary and no decisions or recommendations from this advisory group constitute binding obligations or mandatory actions of any of its members.[xviii] While both the IAWN and the SMPAG are significant steps towards a coordinated international response to NEO threats, they are also merely coordinating and advising bodies between national agencies, discussing planetary defense topics without undertaking binding commitments, and the SMPAG meets only twice a year for only a few days each session.

These international groups have taken some initial steps towards effective global coordination, at least in the clarification of issues, concepts, and opportunity areas, but in their documentation and work, they make it clear that planetary defense is and will likely remain a national issue on some fronts, with national resources focused on national responses—which they form an internationally coordinated response

3.4 Planetary Defense at the Regional and National Level

Advancements in planetary defense actions are also taking place at the national level, with efforts to advance science and technology capabilities, and some focus on coordination, communication, and the other social and political aspects of planetary defense.

In the US, NASA has a dedicated office and staff, called the Planetary Defense Coordination Office (PDCO).[xix] The PDCO, situated at NASA Headquarters, is tasked with early detection, tracking, and characterization of potentially hazardous NEOs, studying strategies and technologies for mitigation impacts, and leads in coordinating US Governmental planning for responses to an actual impact threat. In that sense, the PDCO has both technological as well as policy and administrative priorities. The PDCO also manages the Near-Earth Object Observations Program, which was congressionally mandated in 2004 to find, track, and characterise at least 90 percent of the predicted number of NEOs that are 140 metres and larger in size.[xx]

Planetary defense in the US is also notable for having some level of national high-level coordination, most recently articulated in the *National Preparedness Strategy & Action Plan for Near-Earth Object Hazards and Planetary Defense*, finalised by the National Science and Technology Council in 2023, and updating a prior plan from 2018.[xxi] The 2023 National Preparedness plan clarifies American national planetary defense priorities into six national goals, each supplemented with strategic objectives and action tasks. The goals are

- Enhance NEO Detection, Tracking, and Characterization Capabilities;
- Improve NEO Modelling, Prediction, and Information Integration;
- Develop Technologies for NEO Reconnaissance, Deflection, and Disruption Missions;
- Increase International Cooperation for NEO Preparedness;
- Strengthen and Routinely Exercise NEO Impact Emergency Procedures and Action Protocols; and

- Improve U.S. Management of Planetary Defense through Enhanced Interagency Collaboration

It should be noted that NASA is not the only space agency with planetary defense activities. The European Space Agency (ESA) has a Near Earth Objects Coordination Centre (NEOCC), located at ESA's ESRIN facility in Frascati, Italy.[xxii] The NEOCC aims to coordinate and contribute to observing small Solar System bodies in order to evaluate and monitor NEO threats. It does this through a network of telescopes owned, funded, or in scientific agreement with ESA.[xxiii]

4 Known Unknowns

The good news for our planet and its inhabitants is that there are no *currently–known* asteroids larger than 140 metres in size which have a significant chance to hit Earth for the next 100 years.[xxiv] Any relief felt about this fact must be tempered with the additional fact that, to date, less than half of the *estimated* 25,000 NEOs which are 140 metres and larger in size have been found. It is these "known unknowns" larger than 140 metres which provide the rationale to continue searching the skies, and planning space and Earth–based planetary defense.

In 2005, the National Aeronautics and Space Administration Authorization Act tasked NASA with planning and implementing a Near-Earth Object Survey and finding 90% of the predicted size of the population of NEOs 140 meters in diameter or larger within 15 years of the passage of the Act.[xxv] This goal has not been reached, and Figure 2: *Near-Earth Asteroids Discovered, as of August 2022*, illustrates that approximately just over 10,000 objects 140 meters in size or greater were found by August, 2022.

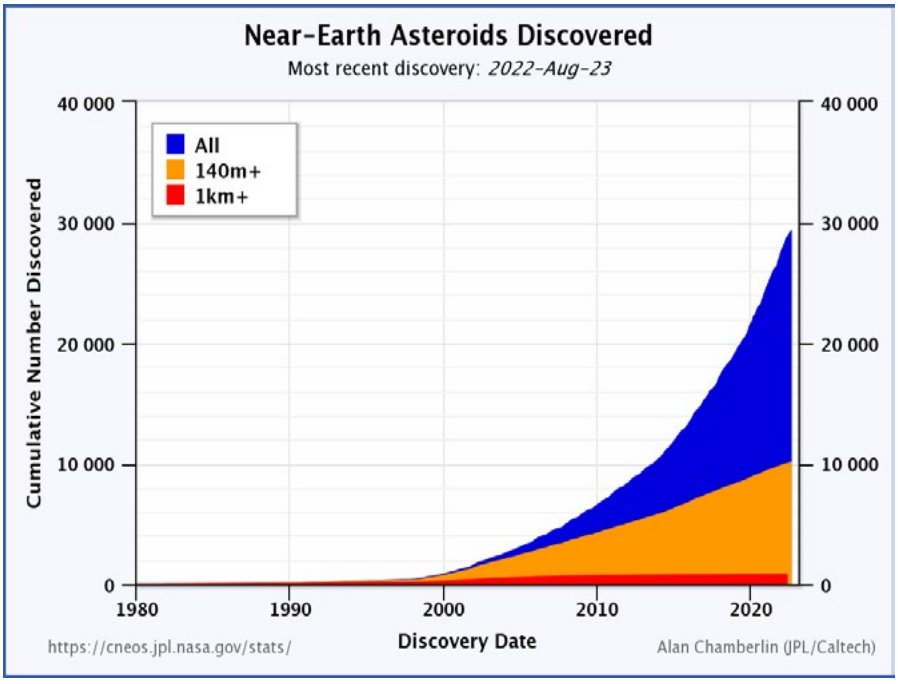

Figure 2: *Near-Earth Asteroids Discovered, as of August 2022*.
Source: Center for Near Earth Object Studies, Discovery Statistics
https://cneos.jpl.nasa.gov/stats/totals.html

Figure 3: *Near-Earth Asteroids Discovered, as of August 2023* is an update of Figure 2, one year later, showing that the total number of detected NEOs has passed the 30,000 mark, while the number of objects 140 meters or greater remains just over 10,000.

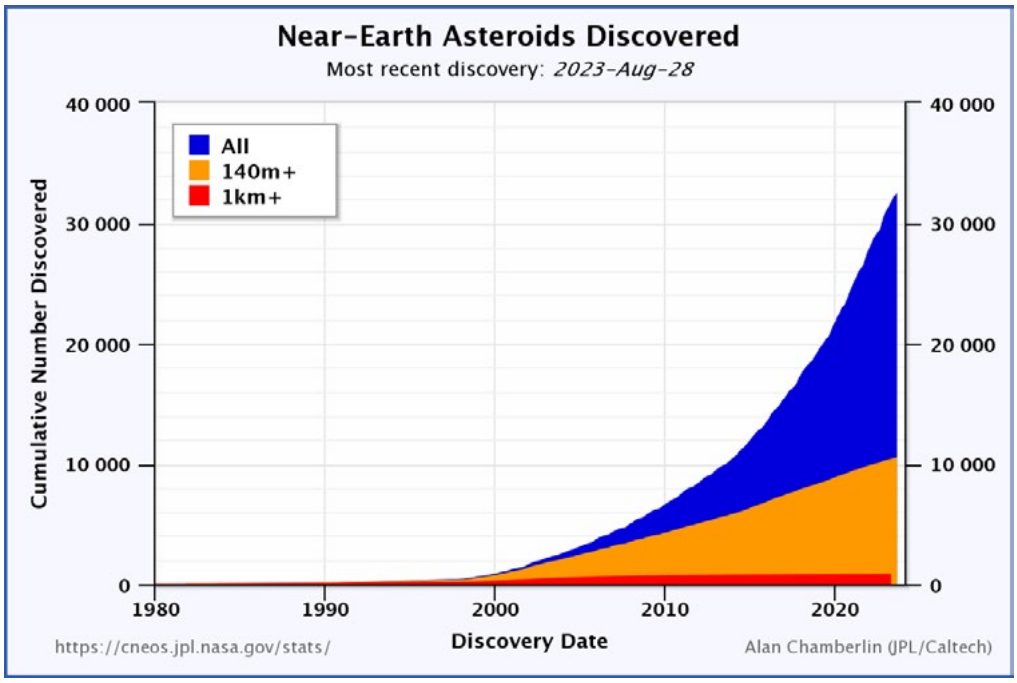

Figure 3: *Near-Earth Asteroids Discovered, as of August 2023*.
Source: Center for Near Earth Object Studies, Discovery Statistics
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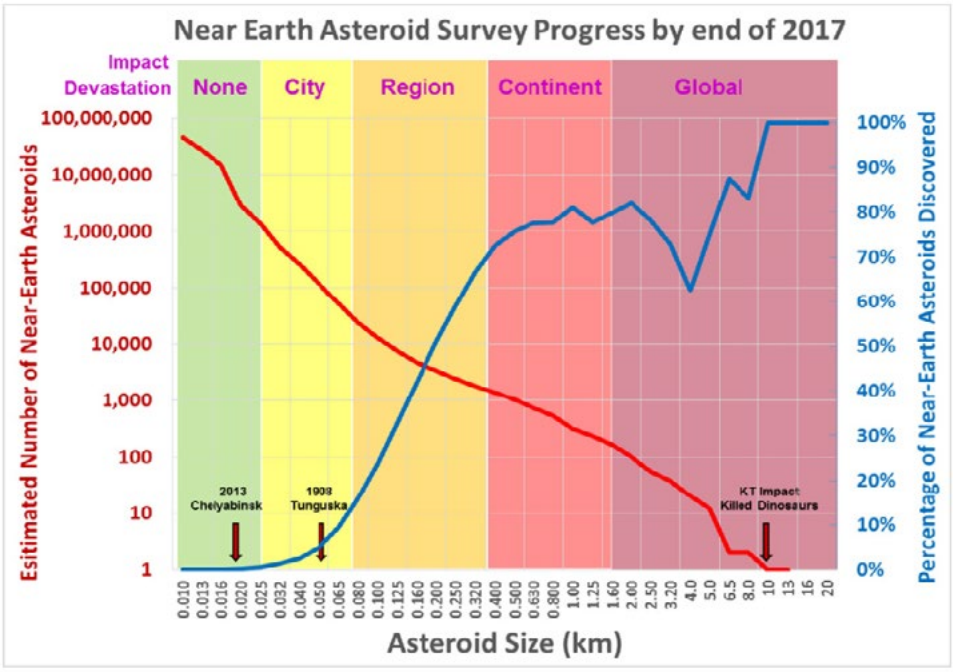

Figure 4: *Near-Earth Asteroid Survey Progress by end of 2017.*
Source: National Science Council/NASA PDCO.[xxvi]

Figure 4: *Near-Earth Asteroid Survey Progress by the end of 2017* illustrates the slow but steady rate of NEO discovery, with discovery totals for asteroids larger than 140 meters displayed in an orange band (the banded portion third from the left) and those larger than 1 km in size displayed in red coloured portion (the banded portion second from the right). Figure 4 also shows that while significant results have been achieved in finding NEOs of varying sizes, completion of the catalogue of objects in our solar system has not been achieved. The dark line in Figure 4 sloping upwards to the right illustrates the percentage of found objects of varying size. The colour coded

bands correspond to the Torino scale of threatened devastation, and when compared with the blue line of completed discovery, shows that (except for the very largest NEOs) there are significant shortcomings in finding NEOs of varying sizes. For asteroids 0.400 km in size (i.e., 400 metres) in the centre of the table, and just inside the light-red coloured threshold for continent-wide devastation, there are an estimated ~1,000 NEOs in our solar system (the red line), and yet only 70% of them have been discovered (the blue line). As many as 25,000 objects larger than 140 meters in size are predicted to exist. As of mid–2023, approximately only 42% of this predicted population of NEOs (capable of causing regional destruction) have been found.[xxvii] Completing our census of small objects within our solar system for NEOs across this entire range of sizes is one of the main tasks in any effective planetary defense.

5 Stressors on NEO Threat Decision Making

There will be numerous stressors degrading the effectiveness of decision makers responding to a NEO threat. On the one hand, the science and technology capabilities assisting planetary defense will continue to advance. This means that the detection and characterization of potentially hazardous NEOs will continue to develop, and the catalogue of NEO objects will be continually refined, updated, and will eventually near completion.[xxviii] NEO threat response, such as Earth-based and even space-based technologies for NEO redirect may also come online in the years to come, especially after the NASA DART mission and its successors. However, for the foreseeable future, these technological developments will not ease a number of stressors placed on planners and decision makers.

5.1 Public Perceptions

It is not inconceivable that many actors (the public, commentators, pundits, authorities, the media, etc.,) will react with conspiracy theories, spin, fear, “fake news”, propaganda, and blaming others. Misinformation and disinformation may run rampant. From a basic view, if your country is predicted to be the target of an asteroid strike while other countries will be missed, a human reaction along the lines that ‘surely, someone somewhere is responsible for this’, as well as the feeling that the devastation threatened is unfair, unfairly distributed, and undeserved are all understandable reactions. Blaming others for their inaction, wrong action, and even their malice, might serve as a venting mechanism for those suffering but surviving a NEO strike. In many ways, the COVID-19 global pandemic is an example of how populaces, national decision makers, intergovernmental organisations, and various institutions and authorities react and respond to uncertain, indiscriminate natural risks for which no entity is to blame.

5.2 Who is in Charge Here?

The first stressor that will degrade NEO response is organisational in nature, in that there will likely be no single authority, or organisation, which is clearly tasked with NEO response, either at the national or at the international level. Some international coordination has already occurred on planetary defense, but it will be sorely tested when humankind is faced with a real NEO threat.

Additional to this, there will also likely be no predetermined rubric for specific actions, with clear thresholds triggering specific responses. The SMPAG has already developed some guidance in its *Recommended Criteria & Thresholds for Action for Potential NEO Impact Threat* document, but it should be remembered that this is merely recommendatory action, and is non-binding.[xxix]

Married to this, when faced with a real and credible threat, there will likely be bureaucratic infighting between different agencies with different mandates and authorities. Absent a clear, pre-existing agency with a specific mandate, funding, and capability to respond to a NEO strike, there will certainly be time wasted in infighting, and in competency, mandate, and jurisdictional

feuds. This confusion will likely be polycentric, i.e., spanning international as well as a variety of national fora—including civil and military divides—and this could quickly lead to politically charged differences in opinion on how to proceed, which will further waste time. Is space-based NEO redirect a task for civil space agencies, or for the military? If for the military, how to reassure the international community of the peaceful nature of these capabilities?

On the national level, can a government act as a coordinated whole, with a "one government" approach, or will there be battles over competency and jurisdiction to act. Can a single government mobilise its population, including potentially evacuating entire areas threatened by a potential NEO strike? Would laws have to be in place beforehand, akin to marshall law, for governmental authorities to effectively evacuate entire cities, states, or regions? If the NEO strike is predicted to threaten multiple states, these become international questions with additional layers of complexity.

5.3 The Clock Is Ticking

There will be time pressure to make decisions, which will put further pressure on potential actors to act. The NEO is getting closer to Earth, and effective NEO responses might become less effective if they are delayed. Some NEOs may be spotted years, even decades, before their closest approach or potential impact. Other NEOs may be spotted only months, weeks, days, or even hours before their impact. Planning for emergency NEO decision making will be negatively affected by this wide discrepancy, as a NEO threat of a few months may allow for different planning procedures than a NEO threat only days or hours away, and these different scenarios may likely require different protocols for response.

Regardless of how soon the strike is, time will remain of the essence. However, this stress will be sharply contrasted to a desire to wait for more data and evidence to refine one's understanding and predictions of the NEO threat. In decision making, this is sometimes known as the "closing" problem, where there is an incentive to keep the status quo, and to continue to amass and ingest further information and data before making a decision—lest an opportunity for a better-informed later decision is missed.[xxx]

There is also something akin to the "fog of war" affecting decision makers, whereby information about the NEO is changing (and will likely continue to change), and there is information about the NEO which will likely never be known but which might be crucial to a response, and the fact that different actors in a NEO response will be differently-informed or likely have access to different data about the NEO threat. Amidst this "fog" or "twilight" of uncertainty, decisions and actions are needed in a timely fashion.

5.4 The Perfect is the Enemy of the Good

In the early days of the COVID-19 pandemic, officials from the World Health Organization stressed that time was of the essence, preparedness was crucial, and that it is better to act and make mistakes than to fail to act. Michael Ryan, Executive Director of the World Health Organization's Health Emergencies Programme, summarised his lessons in emergency preparedness as "act fast, and have no regrets", "the greatest error is not to move" and "speed trumps perfection."[xxxi] He also stated in the context of emergency preparedness, "if you need to be right before you move, you will never win." These pearls of wisdom may apply to planetary defense in a variety of contexts.

The need to know with certainty the consequences of your actions can be paralysing. Henry Kissinger has written about the hazards faced by governmental decision makers, stressing that, despite imperfect knowledge (aka the "fog of war") about objective reality—including about your own capabilities, and the motives and intentions of other actors—emergencies require that

decisions must be made. Therefore, decisions simply must be taken based on imperfect knowledge.

Adding further uncertainty—as time only runs in one direction—outcomes often cannot be strongly tied to particular decisions, and as each situation is unique, past experience only provides so much guidance.[xxxii]

From the perspective of decision makers faced with a NEO threat, it will be wise to contemplate serious and catastrophic outcomes, take all actions possible to avoid those outcomes, and if and when the catastrophe is avoided, it is better to deal with the consequences of over-reacting than to face the consequences of insufficient action. Faced with catastrophic calamities threatened by NEO strike scenarios increasing up the Torino scale, over preparedness and overspending on planetary defense seems difficult to commit.

6 Possible NEO Scenarios

Having gone over the various challenges of planetary defense, including the immensity of the threat posed by NEOs and the stressors on taking effective decisions and actions to plan in advance or respond in a timely and effective manner, the following sections will go through a number of scenarios which might play out, and discuss their legal and political context and implications.

6.1 Scenario 1. After An Earthstrike

Some asteroids are only spotted after their closest approach to the Earth, speeding away on their lengthy orbits before returning Earthward again someday. Other times, meteorites are found here on Earth, the result of Earth strikes that went unspotted in the sky. In both cases, we did not see it coming. Perhaps a great many of the smaller asteroids go undetected as they burn up in the atmosphere or strike Earth without consequences important enough to notice. While the NEO objects catalogue maintained by the scientific community continues to grow, a strong possibility remains that a previously unnoticed NEO might strike the Earth and cause some level of damage and destruction without advance warning.

A state suffering a significantly large impact, but without being able to verify that it was a naturally occurring event, might conceivably fall under the impression that it was being attacked. This might particularly be the case with an airburst, where the NEO strikes the atmosphere with such force that no piece of material is found on the ground, and no impact crater is created. The Tunguska event of 1908 is notable for its lack of impact crater, and only microscopic remains of the impactor itself, which is thought to have burned up somewhere between 15,000 and 30,000 feet in the air.[xxxiii]

Were such an event to happen today, under the right circumstance, it could be initially perceived as the use of a weapon. In fact, many witnesses on the ground in Chelyabinsk, Russia on February 15, 2013 initially interpreted the incoming airburst to be a nuclear strike, presumably from the United States.[xxxiv]

This would potentially be the case if the state suffering the damage lacked the knowhow to spot an incoming asteroid, or could not otherwise confirm the naturally-occurring quality of the event. Additionally, the impacted state might not share or trust NEO data and conclusions by other states. Such a scenario could spiral into the injured state believing that it has been attacked. If foreign experts or other states were to subsequently seek to disprove this suspicion, other difficult questions may arise—such as why no warning was given to the injured state, or even asking why no action was taken.

6.2 Scenario 2. They Don't See It Coming

The corollary to Scenario 1, where the injured state presumes that a NEO strike on its territory was actually an attack, there is a possible situation where a state or other entity performing NEO surveillance detects a hazardous NEO but does not disseminate that information, or warn the threatened state or states. Are there security implications of not warning?

Here, international law, including the principles of international space law as found in the UN treaties on outer space, inform a discussion on the legal context and consequences of this behaviour. The 1967 Outer Space Treaty is the most important source of norms applicable to the exploration and use of outer space, and if a duty to share NEO hazard information exists, its basis should be found in the Outer Space Treaty.[xxxv] Various articles of the treaty could be interpreted as encouraging the sharing of NEO hazard information, although there is no explicit wording anywhere in this treaty or any other of the UN treaties on space that explicitly create this obligation.

Article IX requires that states which are party to the treaty adhere to the principles of cooperation and mutual assistance in their exploration of outer space.

> In the exploration and use of outer space, including the Moon and other celestial bodies, States Parties to the Treaty shall be guided by the principle of cooperation and mutual assistance and shall conduct all their activities in outer space, including the Moon and other celestial bodies, with due regard to the corresponding interests of all other States Parties to the Treaty.

Whether earth-based or space-based, telescopes and other NEO detecting instruments comprise "space exploration" as envisioned in the treaties. Consequently, a NEO-detecting state is obliged to observe these principles of cooperation and mutual assistance. However, information sharing about hazards from space is not specifically found in the text of this article.

Article IX also requires states to show due regard to the corresponding interest of all other states which are also party to the Outer Space Treaty. However, this obligation to show due regard is limited merely to their activities in outer space, rather than all of their space exploration activities—which may comprise Earth-based space observation and exploration. It is therefore difficult to see this due regard obligation as a basis for a duty to warn other states about NEO threats.

Article XI of the Outer Space Treaty is also an information-sharing obligation. It requires states to inform the UN Secretary-General, as well as the public and the international scientific community, of the nature, conduct and results of their activities in space.

> In order to promote international cooperation in the peaceful exploration and use of outer space, States Parties to the Treaty conducting activities in outer space, including the Moon and other celestial bodies, agree to inform the Secretary-General of the United Nations as well as the public and the international scientific community, to the greatest extent feasible and practicable, of the nature, conduct, locations and results of such activities. On receiving the said information, the Secretary-General of the United Nations should be prepared to disseminate it immediately and effectively.

However, and like Article IX, this obligation is limited to those states "conducting activities in outer space" and is further restricted by the phase that such information sharing is only required "…to the greatest extent feasible and practicable". Both limitations could arguably further restrict whether a state sees itself under a duty to inform.

International law also speaks about elementary considerations of humanity, and this might be the only source of law to find, or develop, a duty to warn others about potentially hazardous NEOs. The International Court of Justice (ICJ) decided in 1949 that one of the states before them was under an obligation to inform foreign sea vessels about a minefield in its territorial waters, due to the "general and well-recognized principles" of elementary considerations of humanity.[xxxvi] While the SMPAG Ad-hoc Working Group on Legal Issues discusses these principles as a potential basis for an obligation to warn of NEO threats,[xxxvii] the extension of this principle to phenomena in space, rather than territorial waters, and to the threat of naturally-occurring threats rather than human-made threats, seems tentative and subjective. Other scholars seem to agree, finding that (at present) there is no formal international obligation placed upon states, or any other actor, to warn others about such threats.[xxxviii] There are at least a few instances of states providing warning to other states that an asteroid will enter that state's territory as a meteor, and hopefully this practice can become more frequent.[xxxix]

The security implications of a lack of a duty to warn other states of NEO threats warn of tension and mistrust between states, perhaps akin to state having other intelligence that could be of use to another state, but demurring from sharing such data and findings. Typically, intelligence data concerns human-related threats, such as intelligence regarding international terrorism. However, some intelligence and findings might be related to naturally-occurring threats.

For members of the IAWN, warning is part and parcel of their tasks. Additionally, the amateur astronomy community would not be expected to keep a NEO threat from becoming public knowledge. Nevertheless, a clear and explicit international legal duty to warn creates the conditions for unpredictable and destabilising behaviour in planetary defense.

6.3 Scenario 3. Taking The Hit

Additional to the above scenarios is a situation where a state learns of a NEO which threatens its own territory and/or people. Both the SMPAG Ad-Hoc Legal Working Group and scholars have discussed whether a state's duty to act exists, either to protect its own territory and citizens, or the territory and citizens of other states. Looking at sources of international law, including international space law, the SMPAG Ad-Hoc Working Legal Group found that a state has "a right and an obligation to try to protect its territory and its population, but there is no obligation under international law to assist other States in any particular way or to any particular degree."[xl] However, their analysis looked for inspiration to a host of general instruments, such as the UN Charter and various human rights covenants, including those which speak about a general responsibility to protect in the case of natural catastrophes. These seem plausible as a basis, but could and should certainly be clarified and strengthened.

It seems equally clear that there is no obvious indication that a state must undertake planetary defense actions, whether planetary defense actions on Earth or in space—such as NEO redirection or other space-based measures. As mentioned above, some elementary considerations of humanity might be viewed as a source of law for the development in the future of some duty to undertaking planetary defense, but at present there appears to be no clear international obligation to act either to protect your own state, or to protect other states, from hazardous NEOs.

On a national level, the situation seems different for states (including the US) which have space agencies legally tasked with planetary defense. National space agencies might be tasked with surveying for NEOs, predicting NEO strikes on the surface of the Earth, and even of developing means for space-based planetary defense measures. For these states, the obligation to act stems from national policies and plans, rather than any international commitment.

Common sense seems to dictate that one of the most basic functions of a state is to work toward the health and safety of its citizens, and to safeguard its territory and people from threats,

including naturally occurring and even space-borne threats such as NEOs. That rationale seems to serve as the basis for national planetary defense programs and activities. It does not presently extend to other states and populations.

The security implications of deciding not to act are too complex to forecast beforehand. Deciding not to take Earth-based NEO responses, such as warning the public and mobilising emergency response capabilities may also include the evacuation of large areas, perhaps entire states and regions. If the NEO impact is not predicted for many years or months, this may be feasible. However, accurate NEO Earthstrike predictions that far in advance may be currently impossible. Earthstrike ground predictions may not be refined enough until months or weeks in advance of the collision, so national planners might have to be able to act quickly. Public sentiment and compliance will be a major concern, and there would be significant negative sentiment if evacuation turns out to be unnecessary. Imagine the politician who orders a city to be evacuated, only for the NEO to miss. States with vast territories, and therefore exposed to greater NEO risks than smaller states, will obviously face different decision making situations than smaller states, or states with concentrated populations, or those on coasts.

Space-based planetary defense actions are a different matter than Earth-based responses, and states subject to NEO strikes without space-based response are likewise subject to different decision making than those with space-based NEO response capabilities. However, space-based response is currently rudimentary, and while there have been missions to asteroids, such as the Japanese *Hayabusa* mission, ESA's mission to *Bennu*, only the NASA DART (Double Asteroid Redirect Test) shows development of actual space-based NEO threat mitigation response. DART was an attempt to impact the smaller asteroid Dimorphos, around its larger parent asteroid, Didymos, at 4 miles per second in late September 2022, to test the feasibility of kinetic-impactor response.[xli] Space-based NEO threat mitigation will be the linchpin of any successful future planetary defense capability.

6.4 Scenario 4. Playing The Hero

There are a number of technologies which can be used to respond to a NEO threat, including responses to imminent threats where impact is days or weeks away, and other responses that have longer lead-times. Potential responses including kinetic impactors, gravity tractors, and (in the most imminent and severe threats) nuclear explosive devices.

Regardless of whether a state is under a duty to act (as discussed above) there are legal, political, and security considerations for any state that decides to act. The UN treaties on space, chiefly the 1967 Outer Space Treaty and the 1972 Liability Convention, provide some modicum of context here.[xlii] Firstly, they make states internationally responsible (answerable) for their national space activities, whether those activities are conducted by national agencies or private actors. A subset of international responsibility is liability. Liability is a duty to pay compensation, or be otherwise answerable for damage which you are responsible for. Liability is not a finding that an actor (here, a state) has violated the law, it is merely a finding that one is financially answerable for damage that has occurred. In space law, damage occurring in space is under a fault-based regime, where the space object of one state causes damage to the space object of another state. In space-based NEO threat response, considerations of fault-based liability will likely not happen amongst the participants to the mission. The asteroid is not considered a "space object" under the terms of the applicable legal instruments, and if multiple states are involved in the space-based NEO response (such as a deflection or kinetic impactor mission) these multiple states are all considered joint launching states. Their joint undertaking will likely exempt them from the rationales of space law's victim-oriented regime (although they would be wise to clarify in writing their specific rights and obligations between them). The ambiguities of legal exposure between multiple states in a space-based planetary defense

scenario forecast trouble, and some frameworks and guiding principles could be worked on in a general sense long before a real NEO threat scenario.

In turn, space law creates a regime of absolute liability for damage occurring on the surface of the Earth caused by the space object of a launching state (or joint launching states). The legal standard of absolute liability does not require a showing of intent, or fault, but merely that the damage occurred as a causal consequence of the actions or inactions of a defendant. This regime for absolute liability for space objects causing surface damage was created in contemplation of re-entering launching vehicles and spaceships, or perhaps parts of those artificial vehicles. It was not created in contemplation of NEO redirect missions which fail to achieve their intended results. As such, while the law points towards absolute liability for a NEO mission gone awry which causes terrestrial damage, it is hard to consider such a rigid application of the law plausible in any real scenario.

Regardless of the space law context and consequences, the security implication of NEO redirect missions requires consideration. Should a state take it upon themselves to redirect an incoming NEO, they should do so with a maximum understanding that their best efforts, likely being better than no efforts at all, should be seen by other actors in the most hopeful and needed light possible. A NEO threatening widespread destruction, to which a state responds, should create conditions where the best efforts by that state are respected. To hold otherwise might disable a state from even attempting to redirect or mitigate the NEO threat. It does not seem workable to expose a state conducting planetary defense to liability should their mission fail. Absent actual negligence or malice, planetary defense missions can be seen as a service to the global community, a global public good, for which all benefit, even though only some contribute. And those who contribute to such a planetary defense mission should not have to be unduly delayed by the spectre of absolute liability should their mission fail, in whole or in part. However, specific rules could certainly assist in clarifying these rules, or making new rules which would actually aid states undertaking planetary defense missions.

Additional to these security implications is the question of recourse to nuclear explosive devices, which may be required if the NEO threat is so large, and/or so imminent, that no other NEO response would be adequate. With the clock ticking and perhaps little time for international coordination, can one nation launch a nuclear explosive device—a device substantially similar to a nuclear weapon—into space to destroy an incoming NEO? What nuclear power state would take this risk? Will there be time to reassure other nations, including other nuclear powers? Is such an action in contravention of international law, or does international law even directly regulate such a scenario?

7 Conclusion: Planetary Defense Planning Priority Items

This article has attempted to lay out both the reality of NEO threats, the policy and law contexts for NEO threat responses, and some of the political, legal, and security implications that can be discerned with some minimum amount of clarity in these hypothetical situations, burdened with vague legal and normative guidance.

Having surveyed a few potential scenarios and looked at the applicable laws, it appears that at present, there is no formal international obligation placed upon states, or any other actor, to either track NEO threats, or to warn others about such threats, or to act to prevent or mitigate the effects of the threats posed by NEOs. Furthermore, the legal regime governing space-based planetary defense missions seems ill-suited to foster such potentially crucial activities. However, amidst a legal background that is murky at best and which provides uncertain normative guidance, states would have to take decisions in light of imminent NEO threats, and planetary defense presents uncertain and unsettling security challenges.

Taking the advice of emergency planners in other domains, there is work to be done in preparedness and planning in advance of the day when an actual NEO threat becomes real. The stressors placed upon decision making, including the need to take decisions sooner rather than later, and the conflicting pressure to wait for ever-more refined data and projections, threaten to degrade the decision maker's effectiveness. Clear communication with the public, as well as public trust, will play a significant role in a variety of terrestrial responses to a NEO threat on the day when, not if, it arises.

On the day a NEO threat arrives, the situation will demand rational and coordinated action. We will be better situated to respond to the threat if we have accomplished everything we can do to be prepared *before* that day. This preparedness involves a number of security-related policy and legal steps which can be taken now.

7.1 Fund Planetary Defense

Planetary defense deserves to be considered a public service, akin to meteorology or the emergency preparedness for other naturally-occurring disasters such as tornadoes or earthquakes. As such, planetary defense is simply not planetary science similar to the other planetary science activities, and budgets for planetary sciences should not be used for planetary defense activities (or vice versa), including planetary defense activities such as NEO observation and characterization.

It is a welcome fact, and one that the planetary defense community should fully exploit and capitalize on, that public support for planetary defense is stronger than any other space activity.[xliii] This public support should be used to bolster increased and sustained planetary defense activities and tasks such as completing the catalogue of 140 meter and larger NEOs, building and deploying space-based NEO detection spacecraft needed to complete this task, and other terrestrial planetary defense preparedness objectives.

7.2 Make the Duty to Warn a Clear and Explicit Duty

The duty to warn others about hazardous NEOs should be articulated as a clear, explicit obligation in international and national law. Rather than the vague duty that exists now—which requires subjective determination and proof by international legal scholars, and which may be resisted—a clear and explicit duty to warn other states can be agreed upon. It might be based on the vaguer obligations found in Articles IX and XI of the Outer Space Treaty, as well as other general principles of international law. It should be expressed as an absolute duty to warn others, should you determine with a reasonable degree of scientific certainty based on your means and level of scientific and astronomical capabilities, and regardless of your state's relationship to the state or states endangered by the NEO, that a certain threshold of probability and seriousness of a NEO strike is predicted. This might be a deliverable arising from the UN Committee of Peaceful Uses of Outer Space. However, it might be best received and observed were it to be adopted by the UN General Assembly. National, regional, and multinational commitments might also be warranted, and each would be warmly received by the planetary defense community and national emergency planners.

7.3 Clarify the Duty to Protect

Clarifying that a state which possesses planetary defense capabilities must engage in planetary defense activities would be a step in the right direction. It seems clear that a state must act to protect its own citizens, but this can be made explicit on the national level, through the creation of planetary defense policy and legislation.

The duty to protect other states with your own planetary defense capabilities seems more nebulous, but can be clarified, especially if that duty, obligation, or right is complemented with

the certainty that states undertaking planetary defense are given broad deference so that their valiant efforts not expose them to the liability provisions of international space law.

7.4 Clarify Rights and The Legality of NEO Response Measures

A variety of space-based planetary defense capabilities have been posited, including gravity-tractors, kinetic impactors, and even nuclear explosive devices. The utility of these measures should vary with the NEO threat scenario, with some better suited for scenarios with longer lead times, and others to be held as "last ditch" "hail Mary" efforts. Regardless of technology or method used, a state undertaking the planetary defense measure should not be dissuaded or have their efforts curbed by an exposure of liability provisions.

There also is the question of the legality of nuclear explosive devices, and whether they are violative of arms control provisions, including the prohibition on the placement of nuclear weapons or other weapons of mass destruction into space, one of the foundational pillars of the Outer Space Treaty.[xliv] Clarifying that these devices, intended to save humanity but which appear technologically very similar to nuclear weapons (such as would be used in an international armed conflict, the legality of even this is disputed) is a task that can be accomplished long before we should ever have to use such a device. The security implications of these devices, and the mere mention of nuclear weapons or technology similar to them, has extreme security implications, which is why the lawfulness of their use, only in the most extreme cases, should be rationally discussed and planned for beforehand.

8 Further Reading

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Donald Yeomans, NEAR-EARTH OBJECTS: FINDING THEM BEFORE THEY FIND US (2013).

Bryan Walsh, END TIMES — A BRIEF GUIDE TO THE END OF THE WORLD (2019).

9 End Notes

[i] SMPAG Terms of Reference, https://www.cosmos.esa.int/web/smpag/terms_of_reference_v2#_ftnref1

[ii] A Near-Earth Object (NEO) is "an asteroid of periodic comet having an orbit that brings it within 1.3 astronomical units of the Sun." Report of the Near-Earth Object Science Definition Team, Update to Determine the Feasibility of Enhancing the Search and Characterization of NEOs, September 2017, NASA.

[iii] Donald Yeomans, NEAR-EARTH OBJECTS: FINDING THEM BEFORE THEY FIND US (2013) 109-114.

[iv] Yeomans, pg. 112.

[v] Center for Near Earth Object Studies, Torino Impact Hazard Scale, https://cneos.jpl.nasa.gov/sentry/torino_scale.html

[vi] International Academy of Astronautics, 8th IAA Planetary Defense Conference 2023, https://iaaspace.org/event/8th-iaa-planetary-defense-conference-2023/

[vii] NASA JPL, Center for Near Earth Object Studies, Planetary Defense Conference Exercise 2021 https://cneos.jpl.nasa.gov/pd/cs/pdc21/ "The following image is a projection of Earth surface features onto so-called "b-plane" of 2021 PDC. This is essentially a flattened image of the Earth as viewed from the oncoming asteroid, showing all the regions that could be impacted by potential trajectories surrounding that of 2021 PDC. (While the central part of this image is at risk because it's on the hemisphere facing the oncoming asteroid, the outer ring in this image shows the regions at risk because gravity would bend those trajectories towards impact.) When the uncertainty region is much larger than the Earth, as is the current case, all regions in this projection are at risk of a potential impact. Conversely, regions of the Earth not within this image (e.g., Australia and Indonesia) are not at risk."

[viii] IAU – Minor Planet Center, https://minorplanetcenter.net/

[ix] IAU – Minor Planet Center, The NEO Page, https://minorplanetcenter.net/iau/NEO/TheNEOPage.html

[x] United Nations General Assembly, International cooperation in the peaceful uses of outer space (A/RES/68/75) 16 Dec. 2013, https://documents-dds-ny.un.org/doc/UNDOC/GEN/N13/443/95/PDF/N1344395.pdf?OpenElement ("8. Welcomes with satisfaction the recommendations for an international response to the near-Earth object impact threat, endorsed by the Scientific and Technical Subcommittee at its fiftieth session and by the Committee at its fifty-sixth session").

[xi] United Nations Office for Outer Space Affairs, Near Earth Objects, https://www.unoosa.org/oosa/en/ourwork/topics/neos/index.html

[xii] ESA, SMPAG, Summary of the 18th Meeting of the Space Mission Planning Advisory Group (SMPAG) 9 & 10 February, 2022 https://www.cosmos.esa.int/web/smpag/meeting-18-feb-2022-

[xiii] Space Mission Planning Advisory Group, https://www.cosmos.esa.int/web/smpag/home

[xiv] SMPAG, Terms of Reference for the Near-Earth Object Threat Mitigation Space Mission Planning Advisory Group v.2.0, (2019), https://www.cosmos.esa.int/web/smpag/terms_of_reference_v2

[xv] SMPAG Members: AEM (Mexico), ASI (Italy), BELSPO (Belgium), Czech Republic, CNSA (China), CNES (France), DLR (Germany), ESA, FFG - Austrian Research Promotion Agency (Austria), ISA (Israel), JAXA (Japan), KASI (Korea), NASA (USA), ROSA (Romania), ROSCOSMOS (Russian Federation), SSAU (Ukraine), SUPARCO (Pakistan), UK Space Agency (UK). The Brazilian Space Agency (AEB) submitted their application in February 2022. ASE, COSPAR, ESO, IAA, IAU, SWF, and UNOOSA are SMPAG observers.

[xvi] SMPAG, Terms of Reference for the Near-Earth Object Threat Mitigation Space Mission Planning Advisory Group v.2.0, (2019), 3) Legal and policy aspects.

[xvii] *Ibid.*

[xviii] SMPAG Terms of Reference: "9. Terms and Conditions. These ToR demonstrate the mutual interest of the Members of the SMPAG to exchange information on planetary defense and to develop recommended responses. These ToR do not establish any obligation or legal requirement to do so, nor do they establish any obligation to conduct any particular cooperative activity. Each Member shall provide its own funding and resources for its activities. These ToR may be modified or terminated by consensus of the Steering Committee."

[xix] NASA Planetary Defense – Planetary Defense Coordination Office, https://www.nasa.gov/planetarydefense/overview

[xx] NASA, Planetary Defense – Near-Earth Object Observations Program, https://www.nasa.gov/planetarydefense/neoo

[xxi] National Science & Technology Council, *National Preparedness Strategy & Action Plan for Near-Earth Object Hazards and Planetary Defense* (2023), https://www.whitehouse.gov/wp-

content/uploads/2023/04/2023-NSTC-National-Preparedness-Strategy-and-Action-Plan-for-Near-Earth-Object-Hazards-and-Planetary-Defense.pdf (herein 2023 National Plan)

[xxii] European Space Agency, Near Earth Objects Coordination Centre https://neo.ssa.esa.int/

[xxiii] European Space Agency, Near-Earth Object Coordination Centre, NEOCC Observing Facilities, https://neo.ssa.esa.int/neocc-observing-facilities

[xxiv] Bryan Walsh, END TIMES — A BRIEF GUIDE TO THE END OF THE WORLD (2019) 24.

[xxv] Congress.gov, S.1281 - National Aeronautics and Space Administration Authorization Act of 2005, https://www.congress.gov/bill/109th-congress/senate-bill/1281/text

[xxvi] 2023 National Plan note xxi, pg. 2, footnote 19. For a 2018 update, *see* Planetary Defense Coordination Office, slide 12, https://science.nasa.gov/science-red/s3fs-public/atoms/files/LJohnson%20PDCO%20NEOO%20Brief%20to%20PAC%20Feb%202018_TAGGED_v2.pdf

[xxvii] 2023 National Plan, note xxi, pg. 2.

[xxviii] It should be mentioned that the NEO catalogue will likely always need monitoring, especially for those objects that will have a close flyby to Earth, and to more accurately predict future flybys.

[xxix] Space Mission Planning Advisory Group, *Recommended Criteria & Thresholds for Action for Potential NEO Impact Threat* (2017), https://www.cosmos.esa.int/documents/336356/1879207/SMPAG-RP-003_01_0_Thresholds%26Criterion_2018-10-18.pdf

[xxx] Walsh, note xxiv, pg. 45. ("There's an inevitable trade-off in asteroid deflection—the more time astronomers are given to observe an asteroid, the more precise impact probability and any risk corridor will be, but that leaves less time for a deflection effort, which would almost certainly take a decade or longer to plan and complete.")

[xxxi] Michael Ryan (WHO Health Emergencies Programme) at daily press briefing on COVID 19, 13 March 2020, https://youtu.be/AqRHH6e-y6I

[xxxii] Niall Ferguson, HENRY KISSINGER — 1923–1968: THE IDEALIST, pgs. 871-874, 872 "The key point for Kissinger was the uncertainty that must inevitably surround all strategic decisions…. Unlike the intellectual, the policy maker 'is part of a historical process and is making irreversible decisions that becomes the factual basis for the next decision'…. Just as the policy maker can never know, once Option A has been selected, what would have happened had he chosen Option B, so the historian cannot know."

[xxxiii] Encyclopedia Britannica, *What Is Known (and Not Known) About the Tunguska Event*, https://www.britannica.com/story/what-is-known-and-not-known-about-the-tunguska-event

[xxxiv] Walsh, note xxiv, pg. 49.

[xxxv] Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies, 27 January 1967 (herein Outer Space Treaty). As of 2023, 111 countries are parties to the Outer Space Treaty.

[xxxvi] Corfu Channel, Judgement of April 9th, 1949: ICJ Reports 1949, p.4, p.22.

[xxxvii] Ad-Hoc Working Group on Legal Issues to SMPAG, *Planetary Defense: Legal Overview and Assessment – Report by the Space Mission Planning Advisory Group (SMPAG) Ad-Hoc Working Group on Legal Issues to SMPAG* (2020) (herein Ad-Hoc Working Group Report).

[xxxviii] Lyall & Larsen, SPACE LAW — A TREATISE, 258.

[xxxix] Yeomans, pgs. 125-127, detailing the first instance of asteroid discovered before it reached the Earth, and its impact time and location predicted in advance. Tim Spahr of the Minor Planet Center, then NASA HQ and JPL, and eventually multiple US governmental offices including the White House were given advance notice of the asteroid predicted to land in Sudan. However, there were no formal relations between the US and Sudanese governments.

[xl] Ad-hoc Working Group Report, note xxxvii, pg. 3.

[xli] NASA, DART, https://www.nasa.gov/planetarydefense/dart/dart-news *and* DART Team Confirms Orbit of Targeted Asteroid (29 Aug. 2022), https://www.nasa.gov/feature/dart-team-confirms-orbit-of-targeted-asteroid

[xlii] Outer Space Treaty note xxxv above; Convention on International Liability for Damage Caused by Space Objects, 29 Mar. 29 1972.

[xliii] Pew Research Center, *Majority of Americans Believe it is Essential that the U.S. Remains a Global Leader in Space* (2018), ("When asked to rate the importance of nine of these missions, majorities of Americans say a top priority for NASA should be monitoring key parts of the Earth's climate system (63%) or monitoring asteroids and other objects that could potentially collide with the Earth (62%)". https://www.pewresearch.org/science/2018/06/06/majority-of-americans-believe-it-is-essential-that-the-u-s-remain-a-global-leader-in-space/

[xliv] David Koplow, *Exoatmospheric Plowshares: Using a Nuclear Explosive Device for Planetary Defense Against an Incoming Asteroid*, Georgetown Law Faculty Publications and Other Works, (2017) https://scholarship.law.georgetown.edu/facpub/2197