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Eloy PEÑA ASENSIO
Bachelor of Aerospace Engineering from the Polytechnic University of Madrid, Master in Aerospace Science and Technology from the Polytechnic University of Catalonia and Master in High Energy Physics, Astrophysics and Cosmology from the Autonomous University of Barcelona.
Affiliation: 1) Autonomous University of Barcelona (UAB) 2) Institute for Space Sciences (ICE, CSIC)

E-mail: eloy.pena@uab.cat

Alberto CORONEL TARANCÓN
PhD in Philosophy from the Complutense University of Madrid with a Master's degree in Epistemology of Natural and Social Sciences. He is currently a Margarita Salas Postdoctoral Researcher (Eu-NextGeneration) and coordinator of the Philosophical Laboratory of the Anthropocene and Degrowth.
Affiliation: Complutense University of Madrid (UCM)

E-mail: acoronel@ucm.es

Elisa SIMÓ SOLER
PhD in Law from the University of Valencia, Master in Law and Gender Violence, Master in Advocacy and Double Degree in Law and Political Science and Public Administration from the University of Valencia. She is currently a Margarita Salas Postdoctoral Researcher (Eu-NextGeneration).
Affiliation: University of Valencia (UV)

E-mail: elisa.simo@uv.es

Foresighting cosmic impact threat: planetary risk scenarios and legal-political challenges

Abstract

The Earth could once again face the impact of a large object from the cosmos. This plausible, if unlikely, scenario exposes us as humanity to an unprecedented paradigm. The development of planetary defencee strategies becomes essential, as does the need to define their regulatory framework for enabling its legal and political articulation while respecting human rights. This paper offers a prospective and transdisciplinary analysis based on a rigorous review of the current scientific-technical capabilities of asteroid mitigation. In turn, it examines the political-legal and bioethical implications of various scenarios derived from the threat of cosmic impacts. Through an extrapolation exercise, we propose the figure of the impact refugee and the deterritorialized state by adopting climate refugees and environmental risks as a reference. Taking into account geopolitical conflicts and the multiplicity of actors involved, the article concludes with the need to generate a prevention system that guarantees democratic for decision-making procedures in the face of catastrophic scenarios.

Keywords

Planetary defense, Cosmic impact, Foresight, Refugee, Deterritorialized State.

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1. Introduction

The activity of our solar system has been violent enough to shape our planet, but it has also provided long periods of stability in which human life has been able to flourish. Until the 20th century, the study of planetary-catastrophes was associated more with mythological and religious language than with what we would contemporaneously call scientific knowledge. Today we live in an age where science and technology have revolutionised our understanding of the universe and our understanding within it. This learning process has also made us aware of threats that had gone unnoticed for thousands of years. By observing the craters of the Earth and the Moon, we have discovered that our "cosmic neighbourhood" harbours multiple threats to the survival of human life (Morrison *et al.*, 1994).

In popular culture, the threat of an asteroid impact with the Earth is deemed closer to science fiction than real science. From *Armageddon* to the more recent *Don't Look Up*, a gigantic rock heading for Earth is one of doomsday cinema's favourite clichés. The danger of impact has often been misunderstood or exaggerated for the purposes of clickbait (Shafer *et al.*, 2013; Peterson and Thompson, 2020). But while culturally relegated to the realm of fiction and sensationalism, the threat posed by extraterrestrial objects is a source of growing interest and concern for the international scientif community.

Indeed, the possibility of a cosmic impact scenario in the near future cannot be ruled out. Due to the almost random nature of the encounter of objects in the solar system, i.e. the collision of space rocks, asteroids, comets and planets as they move around the Sun, we may be faced with this problem in the coming decades. The analysis of cosmic hazards reflects important similarities with environmental risks and, as discussed in this paper, suggests that prevention and mitigation strategies designed for the risk of environmental impacts can serve as a model for cosmic impacts. For example, evacuation and governance arrangements for displaced populations, the legal status of the refugee, reflections on the configuration of the state, as well as communication and risk awareness strategies, would be useful in both scenarios.

We know that an asteroid impact has triggered a mass extinction event, and that a cosmic collision of such proportions could happen again (Morrison, 1992; Trigo-Rodriguez, 2022). Even if the probability is not significant in the life of one generation, each generation, to the extent that it inherits a habitable planet, has a bioethical commitment to the defence of the planet that will be inherited by generations to come. In this sense, planetary defence is part of the so-called *future-oriented* ethics and an alternative to ethical *presentism*: our action or inaction affects not only *existing* life, but also the life of future generations.

Faced with the risk of potentially catastrophic threats to subsequent generations, planetary defence takes on what Hans Jonas called the "categorical principle of responsibility, whereby one accepts the duty to act in such a way that the effects of

one's action are compatible with the continuance of genuine human life on Earth" (Jonas, 1994).

Applied to the duties of planetary defence, this principle urges us to approach the very problems and tasks of planetary defence —the goal of which is to defend the Earth from the threat of celestial bodies— beyond techno-optimism and technological solutionism, by which the defence of terrestrial life against the potential catastrophic effects of a cosmic impact can be carried out without having to consider the legal and political elements involved in its operations. Against this approach to the range of challenges it presents, we argue that planetary defence will require the deployment of technological, political and legal forms that are unprecedented in human historyforms of cooperation that do not exist in current practice and on which the prevention of catastrophic scenarios linked to the risk of cosmic impact greatly depends. In turn, we argue that the objectives of planetary defence are perfectly compatible with the prevention of catastrophic scenarios linked to climate change and other environmental risks, so that progress in prevention and mitigation with respect to cosmic impacts could in turn serve to prevent and mitigate environmental hazards.

It is essential to anticipate the future creatively and thoroughly in order to prepare for possible challenges that may arise. The scenario method used in this work allows for the creation of coherent and imaginative stories about alternative futures, from the most expected to the least likely (Bishop, Hines and Collins, 2007). By extrapolating current knowledge to plausible scenarios from a transdisciplinary perspective, we can identify threats that could arise in the future and identify strategies to adequately prevent risky situations.

The paper begins by reviewing the background to cosmic impacts and the current state of our response capacity. It then analyses three similarities in the study of cosmic and environmental risks , which serve as a starting point for the analysis of the legal-political issues raised by the threat of cosmic impact. This forward-looking study begins with different scenarios posed by the threat of a real cosmic impacts , based on the current state of science and tecnology: impact warning, failed deflection, partial deflection and total deflection. This is followed by proposals on recognising impact refugees and land-lost states, and reflections on new forms of governance. A review of the regulatory framework is made before concluding with a set of proposals for the future.

2. Background: cosmic impacts

In 2013, a 19-metre diameter rock passed unnoticed by observatories around the world when it struck the Russian city of Chelyabinsk. But it was not missed by the hundreds of eyewitnesses who recorded the event (Brown *et al.*, 2013). The blast wave itself and the energy it radiated as it burned in the atmosphere injured 1,600 people. A major impact occurred in the Siberian Tunguska mountain range in the early 20th century, devastating a forest area of 2,000 km^2 (Chyba *et al.*, 1993). While there was

no loss of life, if it had occurred in a densely populated area the casualties would have numbered in the hundreds of thousands.

There is evidence that the precursor to the last mass extinction event was an asteroid impact: a rocky object over 10 km in diameter that created the Chicxulub crater (Gulf of Mexico) causing, and in addition to the devastation of the impact itself, caused sudden climate change by blocking sunlight and cooling the global temperature (Álvarez *et al.*, 1982; Brugger *et al.*, 2017). It is estimated that events of this type occur every 100 million years, and with this impact having occurred 67 million years ago, statistically, we are in the last third for receiving another impact of similar magnitude (Chapman and Morrison, 1994).

Thanks to the work of numerous scientific groups and the support of space agencies, the reality of the cosmic impact hazard has been recognised. Today, much effort is devoted to planetary defence: Near-Earth Object (NEO) Observation and Tracking programmes, risk assessment and classification of Potentially Hazardous Objects (PHOs), development of mitigation strategies and legal-political preparedness for human reaction to a possible asteroid or comet impact (Atkinson *et al.*, 2000; Larson, 2006; Chodas, 2015; Baum, 2018). Hereafter, for ease of reading, we will refer exclusively to an asteroid impact.

For the first time, the human species is aware of the cosmic violence that surrounds planet Earth. Even so, it is estimated that we have currently observed only one third of Earth orbiting objects capable of causing regional damage (140 metres in diameter with an estimated impact frequency of 5,000 years) and there is still 10 % of NEOs larger than 1 kilometre (capable of causing global damage and up to 1 billion casualties) to be detected (NASA, 2006; Mainzer *et al.*, 2014).

3. What is our capacity to respond?

In recent years, proposals for asteroid impact mitigation proposals (e.g. kinetic impactor, ion beam, gravity tractor, nuclear device, etc.) have proliferated, suggesting a promising outlook for avoiding catastrophic collisions (Weisbin, 2015; Anthony & Emami, 2018). However, none of these technologies is enough to provide effective defences against a large celestial body heading towards Earth, so new and increased technical efforts will be needed (Rivkin *et al.*, 2023).

Some of these options, explosives in general and nuclear in particular, may be counterproductive. The former, due to the risk of fragmentation of the object by increasing its effective area of impact and preventing future mitigation attempts (Syal *et al.*, 2013). The latter, because of the risks of nuclear war and violent conflict (Baum, 2019). The correction of an asteroid's orbit, also called *deflection*, is a prospective strategy to avoid impacts with the Earth, especially the Kinetic Impactor, as demonstrated by the DART space missions (Cheng *et al.*, 2012) and Hera (Michel *et al.*, 2018). The goal

of these missions is to perform the first double asteroid redirection test to assess the ability to deflect a dangerous object by impact of an artificial spacecraft.

The DART mission in September 2022 demonstrated that it is possible to alter the trajectory of a small asteroid through a kinetic impact; the mission slightly deflected the orbit of the asteroid Dimorphos (Daly *et al.*, 2023). However, this success does not mean that we are prepared to face any scenario for every possible collision scenario with space objects. Many aspects of the nature and behaviour of celestial bodies that could threaten our planet remain to be studied, and unknowns such as the structure, composition and mechanical response of the target can make it difficult to predict the outcome (Syal *et al.*, 2016; Tanbakouei *et al.*, 2019).

Furthermore, the responsiveness will be limited by the time of discovery (Greenstreet *et al.*, 2020), which is a random factor: the longer the observation time prior to impact, the more effective the deflection will be. This lack of knowledge, coupled with the inherent inaccuracies of such astrodynamical calculations (Rumpf *et al.*, 2020), makes the collision threat scenario one characterised by uncertainty.

At the 7th Planetary Defense Conference (2021) of the *International Academy of Astronautics* (IAA), researchers from the world's leading space agencies and academic institutions participated in an impact simulation, confirming our current inability to ward off such a danger (IAA Planetary Defense Conference, 2021).

Both circumstances (future uncertainty and current lack of capability) justify the need to develop international strategies and programmes to accompany the development of available technologies. In fact, the growing concern of the scientific community has prompted some countries to make the first moves to include this issue in their state agendas. An example of this is the creation of the Spanish Space Agency, whose Statutes were approved on 8 March 2023 by Royal Decree 158/2023. Article 2(3) sets the objectives of the Space Agency tis e contribution to national security and the promotion of actions conducive to ensuring security and defence objectives, as well as the reinforcement of the necessary coordination to maximise the efficiency and effectiveness of the financial resources available for security, research, innovation, technology, development, industry and programmes in the space field.

As mentioned in the Royal Decree, the space sector is essential for national security and it is stressed that security policies must be based on international cooperation, taking into account all the actors involved. In this way, the Spanish Space Agency has been created to help organise competences and facilitate the use of space capabilities. Although not explicitly stated in the document, it is clear from the government's position that space and planetary defence activities will become part of national security strategies.

Despite these initial efforts, and due to the existing legal vacuum in this area, we are still far from being able to provide a comprehensive and effective response that guarantees human rights and ensures democratic channels of participation and a transparent decision-making process. This observation highlights the link between political science and planetary defence, precisely because of the way in which mitigation

and adaptation strategies that can be useful for defending against cosmic impacts can, in turn, be useful for guiding the defence of populations against environmental impacts.

7. Similarities between cosmic and environmental risks

The nature of climate change could be described as a hyperobject, i.e. objects that are massively distributed in time and space, multidimensional and with seemingly chaotic behaviour (Morton, 2013). As the reports of the Intergovernmental Panel on Climate Change (IPCC) show, this means that the description of catastrophic scenarios and the design of prevention, mitigation and adaptation strategies require interdisciplinary and transdisciplinary cooperation between specialists from different fields of the international scientific community. In the face of this complexity, the identification of formal similarities in the analysis and study of cosmic and environmental hazards can serve to facilitate the prediction of scenarios and the development of action plans. In other words, an asteroid condenses and projects the impact risks that the climate crisis is spreading.

For example, the international community must consider relocation scenarios for populations, which will be required by the extreme weather conditions that some territories experience. Coastal Inuit communities in Canada are suffering from melting permafrost and small islands such as Kiribati, Tuvalu, the Maldives and the Marshall Islands could be submerged in the near future due to rising sea levels. In order to prevent their inhabitants from being left in legal limbo or even becoming stateless, the need to create a comprehensive framework of *hard* and *soft laws* that guarantee the rights of displaced persons was highlighted (Yamamoto and Esteban, 2017; Atapattu, 2014). Similarly, a cosmic impact could risk rendering the affected regions uninhabitable, with the consequent displacement of populations.

Another example comes from the covid-19 pandemic. In the early days of the pandemic, the slogan "the virus makes us all equal" was widely repeated. However, over the course of two years it became clear that the material conditions of both states and individuals were decisive when it came to articulating a response. The same problem could occur in an impact scenario. The threat of an asteroid apparently equals us as a species, any territory and its population can be endangered by a common enemy that does not distinguish between species, ethnicities, nationalities or social groups, but again, response capabilities are diverse. Only a few states and companies have the technology to protect the population.

In short, the new challenges posed by the climate crisis can serve as a mirror for dealing with the problems of an impact on the Earth, and conversely, the challenges posed by the threat of a cosmic impact can be useful for dealing with the risks of the environmental crisis.

In this sense, it is necessary to go beyond interdisciplinarity to transdisciplinary approach to planetary defense. The transfer of methods from one discipline to another is one of the central features of interdisciplinary methodology. Beyond transfer, however, plural methodological integration makes it possible to overcome disciplinary boundaries through what Basarab Nicolescu called the *transdisciplinary* perspective: the "process whereby the boundaries of individual disciplines are transcended to approach problems from multiple perspectives with a view to generating emergent knowledge" (Nicolescu, 1998; Matos and Quesada, 2008). With regard to cosmic and ecological threats, the transdisciplinary study of cosmic and environmental impact risks highlights three major similarities or isomorphisms that are connected and intertwined: (i) prospective uncertainty; (ii) temporal urgency; and (iii) diffuse responsibility for effects.

1. *Prospective uncertainty.* Natural disasters and PHO collision risks involve *high uncertainty*. In both cases, prospective analysis and the design of protocols are the best safety guarantees for affected populations (Velasquez, 2015). Threats from cosmic impacts can be predictable or unpredictable, in the same way as environmental catastrophes. For example, a volcanic eruption, earthquake, hurricane or tsunami can be foreseen or unforeseen (i.e. La Palma volcano eruption). Other weather phenomena such as heat waves, droughts, desertification and glaciation can be predicted even decades in advance. The same could be said of the risk of a collision. In both cases, anticipation is the key factor in reducing fatalities in a disaster. In the face of uncertain phenomena that can abruptly change the habitability of large regions, forecasting and evacuation mechanisms are the best way to protect populations.

2. *Temporal urgency.* Regarding time, the mitigation of the negative effects of a cosmic or environmental disaster is marked by urgency, matching the definition in Law 17/2015, of 9 July, on the National Civil Protection System: "situation of collective risk arising from an event that puts people or property in imminent danger and requires rapid management by the public authorities to address them and mitigate the damage and try to prevent it from becoming a catastrophe" (Law 17/2015). Because of the likely destruction of infrastructure, the urgency of a catastrophic impact means that the range of possible actions on the ground is reduced: if motorways collapse or are destroyed, or if roads and ports are affected, only air (in the absence of airborne dust) and sea transport (depending on the region) would be effective in alleviating the emerging situation. In terms of effectiveness and efficiency, planetary and environmental defence —or a form of integral defence that brings both together (Coronel Tarancón, Simó Soler and Peña Asensio, 2023)— must prioritise detection and prevention strategies over adaptation strategies.

Whether caused by an environmental or cosmic hazard, a disaster situation means that the affected population must be provided with basic services such as water, sanitation, food, shelter, health care and protection. Because of the urgent nature of these services, each requires prior organisation, additional funding, effective immediate

and long-term support, and data to inform decisions and evaluate interventions. The capacity to respond to the emergency derived from cosmic and environmental impacts calls upon the principle of the responsibility to protect proposed by the United Nations (2005): the responsibility of each state and, subsidiarily, of the international community, to protect their populations in crisis situations that involve human rights violations. Its use requires the determination of the humanitarian aim pursued by intervention (impregnated with geopolitical or economic interests) or the recourse to force as a means of resolution (militarising the solution to the crisis), borne from a narrowing of the factual situation and a nuancing of some controversial elements such as its exclusively political (and not legal) nature, with a greater focus on the preventive facet (Añaños Meza, 2009). Therefore, a *non-invasive* protection clause should be added to the responsibility to protect (R2P) principle, otherwise it would not be possible to prevent the use of R2P as a subterfuge for covert interests.

i. *Diffuse or shared responsibility.* For both cosmic and environmental impact risks, it is not always possible to assign ethical or political responsibility in a straightforward or simple manner (Spiegel, 2005). In both cases, disasters could be retrospectively associated with the strategic action and inaction of an indeterminate number of international actors. However, the uneven economic development that has emerged in the 21st century places greater responsibility on those powers with the financial and technological capacity to develop strategies to prevent and mitigate catastrophic impacts. Global defence and environmental sustainability require equitable and fair forms of international cooperation. Because not all countries have the same resources to invest in strategies to prevent and mitigate catastrophic impacts, and not all countries are equally exposed to the planetary effects of such impacts. Therefore, and this is the isomorphism that encompasses all of the above, both planetary defence and environmental sustainability are issues of *global justice*.

ii. *Global justice and international cooperation.* Given current state of science and technology, no single state on its own would not be able to deal with the threat that, if it materialised, would create global damage (e.g, a regional impact causing sudden climate disruption or even earthquakes and tsunamis with global repercussions). Moreover, given the inequality of resources between States and non-governmental organisations, the response according to this material criterion would be completely unbalanced between States with technological means and others without any kind of equiment, not even programmes for sky observation and tracking objects. Therefore, and with a clearly improving track record in dealing with transboundary issues, a mitigation strategy would have to be built on international coordination and the creation of a global network of diverse actors, technological resources, budget and democratic decision-making processes that appeals to global justice in the sense of equal protection and guarantees for all populations without distinction (Packer *et al.*, 2013).

From the four elements outlined above, we can deduce the need for a legal-political approach that transcends the limits of "presentism" (Balashov and Janssen, 2003) and

technological solutionism (Morozov, 2015) that have so far defined the problems and tasks of planetary defence.

5. Prospective analysis of the cosmic impact threat

As noted in the previous section, given our level of scientific knowledge and technological capability, the impact threat scenario is based on uncertainty. Not only because the time of detection and the characteristics of the object are unknown, but also because, even if it is detected in time, accurate prediction of the trajectory and the exact collision point may be beyond our capabilities The degree of unpredictability of a catastrophic event would influence the decision-making process and the choice of protocols. This uncertainty (which shifts from the technological to the political) is one of the major elements that link the tasks and problems of planetary defence with political science.

Anticipating the need for cooperation in the face of the threat of a cosmic impact requires a realistic prospective analysis to facilitate an anticipatory governance strategy and an institutional response to the scenarios resulting from a possible impact. The complexity of calculating the exact point of an impact makes it difficult to discuss possible actions. If a state has the ability to deflect an asteroid and change the impact site, it opens the door to discretion. Ironically, if we do not develop deflection technology, we will not be able to defend ourselves against an asteroid encounter. But if we develop this capability, it unlocks the possibility of deliberate misuse with potentially apocalyptic results (Sagan and Ostro, 1994).

This is the so-called *Real Deflection Dilemma*, which asserts that the development of a planetary defence mission necessarily puts otherwise unthreatened lives and tangible and intangible assets at risk (Schweickart, 2004). This scenario defines the interface between planetary defence, politics and bioethics. What criteria could be used to decide whether or not to change the asteroid's trajectory? Are states capable of making ethical decisions when faced with the threat of an impact? Could more powerful states take unilateral decisions affecting third parties? What effects would they have on international relations? Should priority be given to the defence of territories that are densely populated, industrialised, culturally valuable or ecologically valuable?

Regarding differences due to uneven economic and technological development: how does the techno-epistemic privilege of some states over others (without the means to detect, prevent or modify an asteroid´s course) affect the Real Deflection Dilemma? Given the similarities between cosmic and environmental impacts, one might ask: are we witnessing the permanent diversion of environmental impacts to the countries of the so-called Global South? If the global environmental crisis were to be analysed in the light of this dilemma, would it be possible to speak of an *ecological deflection* to define the diversion of environmental impacts from one state to another?

All these questions constitute a mine of bioethical, legal and political reflections that intertwine the analysis of cosmic and environmental risks, while simplifying the equitable attribution of responsibilities for the pursuit of climate justice objectives (Borrás and Villavicencio, 2021). At the same time, they force us to engage in an imaginative and forward-looking exercise, considering the interference of geopolitical interests with prevention and mitigation strategies. As a regulatory ideal, this approach allows for a reconceptualisation of transnational security according to which: "all security actors have a responsibility to consider the global impact of their decisions" (Burke, 2013).

To address the links between ethics, law, politics and planetary defence, we will begin by differentiating the different scenarios in which humanity could find itself with the current scientific-technical capacity of PHO deflection.

6. Scenario method applied to deflection of dangerous objects

The current scientific and technical capabilities in terms of planetary defence allow us to distinguish four scenarios and the legal and political challenges associated with each of them. Their theoretical construction will depend on transdisciplinary extrapolation rather than mere speculation: it is not a matter of imagining, but of projecting the information we have to build hypothetical scenarios from empirical data. Moreover, to the extent that cosmic impacts constitute complex and multidimensional threats, their analysis can benefit from what Edgar Morin (2007) called the "logic of the included third party", whereby contradictions that are intractable at one level of the problem can be resolved at another. For example, when two sovereign nations enter into a dispute, the environmental value of one territory may be more difficult to restore than the infrastructure of another. In this case, environmental analysis unbalances the contradiction between the legitimate interests of sovereign states.

Using this approach, we differentiate between four main scenarios: impact warning, no deflection, partial deflection and full deflection. As we can see in the figure below (see Fig. 1), different scenarios may share elements, as explained below.

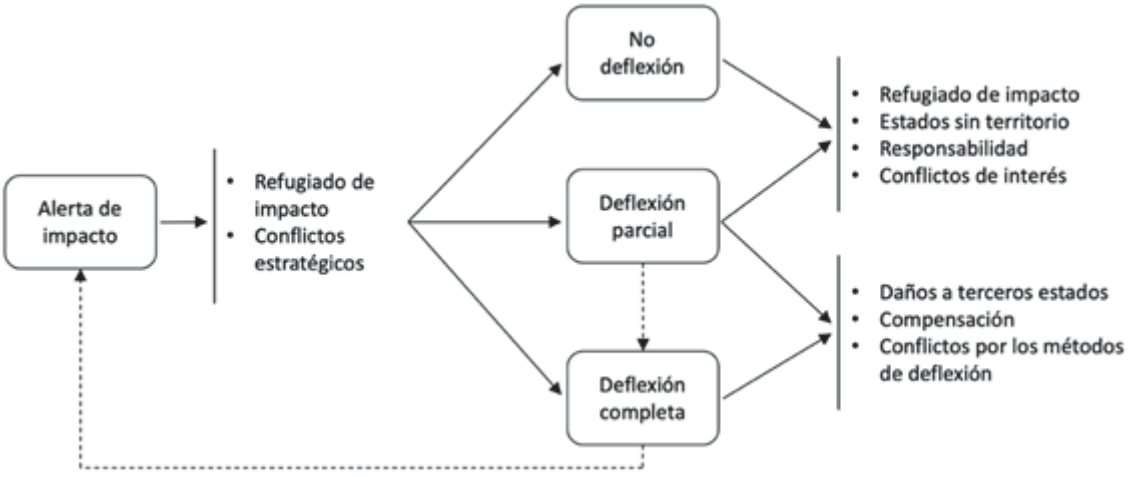

Figure 1. Diagram of the shared elements of each of the cosmic impact scenarios. Source: Author's own elaboration.

6.1. Cosmic impact warning

As mentioned above, there can be a high degree of uncertainty in determining the probability of an impact. It is precisely for this reason that it is necessary to act on the assumption that an impact is certain in order to anticipate the worst-case scenario as far in advance as possible.

Firstly, the mere news of a possible impact could *ipso facto* trigger migration to lower-risk regions or even a global migration to the other side of the world. These population movements, candidates for humanitarian and political crises, could be spontaneous or institutionally coordinated, as well as temporary or permanent. But in any case, they should be backed by a legal framework on the impact refugee (discussed in the following section). In addition, different conflicts could arise over the response strategy selected, as the mere intention to opt for certain mitigation actions would generate tensions between states.

Secondly, one country might interpret as a security threat another state´s attempt to employ a dangerous and questionable technique that would cause further damage. Consider, for example, the use of nuclear explosives. A launch failure could result in a radioactive contamination phenomenon on the ground or at low altitude. Another example would be an explosive mitigation strategy that fails to destroy the asteroid but produces fragments that would remain on the same collision trajectory, enlarging the effective impact area (Syal *et al.*, 2013). This would exacerbate the previous situation, hindering further deflection attempts and threatening new regions rather than reducing risk (Rumpf *et al.*, 2020).

Furthermore, an optimal explosive mitigation method (with a high destructive potential) could exacerbate nuclear tensions between countries (Schmidt, 2019) and should therefore be relegated to the *last resort* category (Baum, 2019). Following this line, a threatened state might rule out the use of nuclear explosives and, if this were the only option, the debate would then arise over the scope of national sovereignty and the non-existent obligation of states to help others (Drube and Haddaji, 2020). There could even be such perverse situations as a state failing to report an imminentf collision in orden to reduce its room for manoeuvre and improve its position in assistance.

On the other hand, to maximise operational control and ensure maximum responsiveness, states could nationalise key enterprises not only for defence strategy, but also for economic recovery. With the increasing need for public-private partnerships and the emergence of aerospace mega corporations, a successful outcome through private sector intervention could force compensation or privileged deals.

6.2. No deflection: failure or inaction

Inaction by the threatened state or a failed mitigation mission could lead to a catastrophic event. The territory could be devastated and its infrastructure (housing,

parliament, hospitals, courts, police stations, businesses, etc.) destroyed. Depending on the damage caused, the previously evacuated population would be temporarily or permanently displaced from their territory (Atapattu, 2014; Ferris, 2010).

First, the existence of an uninhabitable territory, or its physical extinction, suggests a reconfiguration of the nation-state model under the paradigm of land-lost states (as will be discussed below).

Secondly, if the actors involved (states, companies or international organisations) failed to divert or destroy the asteroid, there would be no legal obligation to help the states affected by the failure. In principle, ignoring the request for assistance would not violate any international norm, hence the importance of the principle of *bioethical responsibility* in the development of new international obligations. The States that, at each historical moment, have a decisive technological capacity for the deflection test are *a priori* responsible for the action and inaction within their capacity. Therefore, in order to minimise the negative consequences of neglecting threatened populations, it would be necessary to determine in advance a regime of shared responsibility that defines and delimits the legal effects of decisions.

In this sense, the involvement of a third party in the mitigation strategy could be approached from a cost-benefit analysis in which conflicts of interest would not necessarily disappear. One State might refuse to help another because it is a competitor on the global market or for geopolitical reasons. Conversely, a State could offer its cooperation to a state, which does not have sufficient technological capacity, through unfair negotiations. Indeed, a cosmic impact scenario places the value of living beings, as well as the protection of the planet's biosphere, at the centre of the debate (Schmidt, 2018), especially in a context of climate emergency like the current one, where the defence of human and non-human life is presented as tasks that, far from being incompatible, are strongly pointed out as inseparable by anti-speciesist, ecologist and environmentalist organisations (Horta, 2010; Pendergrast, 2016).

6.3. Partial deflection: diverted impact

This framework includes the deflection actions of the asteroid which, although they may have changed the point of impact, but did not prevent the collision. In this scenario, the asteroid would be partially deflected due to a limited mitigation capability or a mission failure, causing damage to a region that was not originally at risk. All the elements are the same as in the previous framework: migratory phenomena, states losing territory, the call for cooperation, responsibility for the failure of the strategy and conflicting interests. Similarly, a post-deflection impact could occur if there were a succession of unilateral deflections between states to minimise their risks, causing the object to hit a third state other than the one initially threatened.

This would be the case if a first state deflects the asteroid, a second state deflects it again, and the asteroid finally collides with an ocean, causing a tsunami that hits the

coast of a third, previously unthreatened State. The consequences should be analysed, ranging from sanctioning of states to compensation claims by the affected state. Geopolitical interests and lack of technological capacity, as well as disagreements over methods, would again come to the fore.

6.4. Full deflection: deviation without impact

In principle, avoiding the asteroid's impact would count as a success. However, this would not prevent subsequent close encounters typical of the orbits of these objects (Giorgini *et al.*, 2008). The impact hazard could emerge later threatening a new region of the Earth.

Firstly, as in the previous case, a third State not initially on alert could now be at risk, and in the event of a new threat of impact following first deflection, two legal issues would again rise: the reward to the State or entity successfully implemented the defensive strategy and the claim for compensation by the injured State. The assumption of a dangerous re-collision after a deflection poses an additional challenge, since *a priori*, at the moment of deciding to modify the trajectory, the point of impact in a subsequent close encounter could not be accurately foreseen, and the attribution of liability would therefore be highly complex.

The main difference between full and partial deflection is that, with a partial deflection strategy, can anticipate new impact areas. However, in a full deflection it would not be possible to estimate the threatened area in a future close approach, as the orbital dynamics of close encounters multiply the degree of uncertainty in medium- to long-term predictions.

Regardless of the outcome, the mitigation action could be carried out in violation of norms of international law, such as the prohibition on the use of nuclear weapons. This presents an apparent contradiction between respect for the rule of law and the protection of human life. In such case, the triple canon of danger, necessity and consent should be taken into account (Drube and Haddaji, 2020). The limits of national sovereignty in a context of a global threat and the circumstances that preclude the wrongfulness of conduct that would otherwise be contrary to international law, would all need to be re-evaluated.

The design of *pre-agreed* government penalty, compensation or indemnification mechanisms would be a prerequisite for legitimate decision-making. However, conflicting sovereign interests, lack of technological capacity and procedural disagreements would define the most likely rationale. In the partial deflection scenario, for example, states could accept the uncertainty characteristic of the cosmic impact threat as an opportunity to take on a hypothetical *veil of ignorance* (Rawls, 1971): since any region, country or continent could be threatened, it would make sense to formulate rules and procedures independently of which region is threatened. As Francisco Caballero (2006) points out , the agreements linked to this uncertainty

are, as a matter of principle, inseparable from "the acceptance of a set of restrictions imposed in favour of principles of justice".

In all these cases, a development of a body of law requires a thorough knowledge of the specific factual scenarios. Extrapolating current knowledge on techniques and possible outcomes is an essential first step in disaster forecasting and prevention.

7. From climate refugees to impact refugees: land-lost states and new forms of governance

The remote possibility of a territory disappearing completely (or becoming uninhabitable) requires an exercise in conceptual flexibility aimed at rethinking the model of the modern nation-state, the new migratory phenomena, and redefining essential elements such as citizenship and the sovereign authority of the State (Marshall, 2020). This conceptual flexibility contrasts with the normative rigidity with which, until now, the figure of *climate refugee* has been denied legal recognition. However, it is possible to coin the concept of *impact refugee* and to think about their political-legal status by taking the debates around *climate refugees* as a model and a starting point.

The United Nations High Commissioner for Refugees (UNHCR) and the International Organisation for Migration (IOM) do not recognise the term *climate refugee*. One of the main reasons for its rejection lies in the contours of the 1951 Refugee Convention which contains an exhaustive list of circumstances that determine refugee status and which does not allow for an expansive interpretation (Williams, 2008; Biermann and Boas, 2008). The remaining alternatives are to add a protocol on climate-induced migration to the UN Framework Convention on Climate Change, or to create a new specific legal and policy regime, which in this case would address the needs of impact refugees: recognition, protection and, where appropriate, compensation and resettlement (Hartmann, 2010; Kostakos *et al.*, 2014).

As in the case of the proposal on climate refugees, the legal-policy formulation of the *impact refugee* require the consideration of several aspects related to migratory movements: the motives (linked to the possible scenarios outlined above), the duration (temporary or permanent) and the dimension (national or international) (Biermann, 2008). Each of these possibilities would require a specific plan of action by the threatened state, technologically advanced States and the international community.

Unlike a stateless person (a natural person without a nationality), impact refugees would be persons with a nationality and under the protection of the laws of a state that no longer has a territory, i.e., a new figure would emerge, that of a citizen without a territory or *landless*. Underlying this approach is the concept of *ex-situ nationhood* proposed by Burkett (2011):

> "[It would be] a status that allows for the continued existence of a sovereign state, afforded all the rights and benefits of sovereignty amongst the family of nation-states, in perpetuity. It would protect the peoples

> forced from their original place of being by serving as a political entity that remains constant even as its citizens establish residence in other states. It is a means of conserving the existing state and holding the resources and well-being of its citizens —in new and disparate locations— in the care of an entity acting in the best interest of its people."

As an effect of mass migrations, traditional forms of governance would be altered, and a *co-sub-governance* could be projected in a scenario of a territory geographically erased by an impact and a migrated population hosted by another state. This is a form of governance that may require cooperation strategies between the institutions of the displaced and host states, favouring a kind of joint governance or the creation of sub-governance within the framework of the host State. Moreover, it is inevitable to formulate a series of questions aimed at finding solutions to this hypothetical but plausible situation. Would the international community recognise states without territory? Would governments in exile be legalised? Would mobilised populations be relocated to other territories and offered legal protection? In what cases could there be provisional transfers of territory between states? Would the reconstruction of land-lost states be financed? (Douglas, 2017).

Such issues have been discussed in the context of Small Island Developing States (Woodward, 2019). In order to preserve their sovereignty, one camp recommends the creation of *ex-situ* nations based on a system of political trusteeship, governments in exile or land-lost states as possibilities in the field of international law.

Thinking about non-face-to-face governance and the possibilities offered by technology (as seen during the covid-19 pandemic), new forms of virtual governance could emerge with digitised institutions (Fountain, 2014). A sort of meta-nation-state with constitutional bodies hosted on web servers, which would make possible new models of democracy. Although inevitably speculative in nature, the possibility of such a state requires reflection on the factual legitimacy of virtual states, or on the exercise of the legitimate monopoly of violence in a digital environment. Despite their relevance, both problems are beyond the formal and material limits of this paper.

In any case, since this is an area to be explored and proposals are in the pipeline, the sooner the appropriate policies and governance mechanisms are defined, the better off the governments and populations will be in. In this sense, it is important to define the decision-making process from an organic and procedural point of view.

8. Decisions and procedures: towards a democratic planetary defence with due process

Some caveats related to the actors involved in planetary defence are shared with climate migration. The five permanent members of the UN Security Council —the United States, China, Russia, France and the United Kingdom— are some of the largest emitters of greenhouse gases and can take the lead in responding to climate disasters (Hartmann, 2010). The same paradox applies to PHO mitigation strategies.

The same states may have both the technological capacity, and simultaneously have the right of veto. This overlap translates into an excessive concentration of power, which calls for the search for tools to democratise the techno-political oligopoly of planetary defence.

Decision-making conflicts could become more complex assessing the impact on the right of individual or collective self-defence if a state does not have the technological capacity to prepare a deflection mission. In case of a veto, the threatened state could invoke Article 51 of the UN Charter or justify the action as necessary, circumventing the veto in accordance with the law. In this regard, two scenarios arise that merit consideration.

First, the right of veto could be understood as a right of individual self-defence if the deflection strategy potentially affects one of the five permanent members of the Security Council. Second, discrepancies in the assessment of danger could lead to divergent positions on the justification for planetary defence action. Some members may consider that the consequences of the impact are manageable or that the likelihood of the impact does not require mitigation missions, and agree on a threshold that takes into account not only economic balances but also the subjectivity of socio-cultural values (Drube and Haddaji, 2020).

The potential for interference by spurious geopolitical interests remains. As Schmidt (2018) argues, "We can say that everyone tends to want to save the world, but the question is how much of the world they would want to save. For some, saving humanity may be a lever for domestic political objectives." A statement followed by the stark acknowledgement that "there is no reason why we should assume that the *modus operandi* would change in planetary defence". This should urge us to avoid naïve approaches that assume rational behaviour on the part of States for the defence of the planet, thus emphasizing importance of risk governance and the role of intelligence systems for the protection of national security beyond ratified pacts or treaties (García Hom and Moles Plaza, 2013).

In this sense, addressing the decision-making system from a procedural and organic approach becomes a priority. Actors should take into account the influence of politics and power struggles due to the lack of a solid legal framework, as well as the disruption in the exercise of democracy. Without this guarantee, "unique defensive activities can become a destabilising factor, trigger arms races and destroy the balance between major powers, not only in space but also on Earth" (Drube and Haddaji, 2020).

Although they are strictly political aspects, discussions about them should not be separated from the technological sphere and advances in science. It should be determined which institution will be the decision-maker. Will it be technologically capable states, the UN Security Council or a specific *ad hoc* institution? Could an *in extremis* planetary defence action be unilateral? If the purpose is to democratise the decision-making process, would a referendum be a valid instrument? Indeed, these are questions that will require time for reflection, and the answers must be agreed upon in advance in order to avoid conflicts, the tensions of which could be exacerbated

by the immediacy of the decision and the damage caused by failure or inaction. In planetary defence, therefore, the political-legal sphere must be seen as inseparable from technological development.

Taking into account the circumstances of the most vulnerable groups, States must assume that the threat of an asteroid hitting the Earth puts the entire planet at risk, regardless of the final outcome. Anticipatory measures must be taken in international law alongside the safest and most effective mitigation techniques, with particular emphasis on developing democratic solutions to protect humanity from a cosmic threat.

9. Legal framework and proposals for the future

Society and its demands usually precede the law. There are many examples of this general legal dynamic, from lower taxes and the recognition of same-sex marriage, to access to education and bans on single-use plastics. In planetary defence, however, the process must be reversed. Science and law must anticipate the occurrence of the factual event, since it would be inconceivable to wait for a collision to occur in order to regulate the aftermath.

In a situation where a) technological capacity is in the hands of major world powers; b) there are private actors with more power than some states to make decisions with global repercussions; and c) the decision-making process is not pre-defined, the balance of power may be altered. Consequently, some legal aspects must be addressed in the light of geopolitical interests and the likely multipolar distribution of global power in terms of planetary defence.

In any case, a regulatory legal framework should be designed and the actions and responsibilities of states should be defined (Bucknam and Gold, 2008; Rusek, 2022). The *Corpus Iuris Spatialis* is composed of five main instruments ratified by most states (*Outer Space Treaty, Rescue Agreement, Liability Convention, Registration Convention, Moon Agreement*), which do not constitute a specific regulatory regime. They cover questions of reporting and action, the legality of planetary defence methods, the liability regime and related issues such as space debris and the role of non-governmental organisations.

It would be appropriate to start regulating them, bearing in mind that the main drawback is the high degree of uncertainty. Binding agreements should therefore be sufficiently broad enough to build consensus and be tailored to the specific circumstances of the collision. The more detailed the planetary defence strategies, the greater the legal security for states and citizens.

With regard to the system of liability, it would be relevant to approach it from a two-fold perspective: that which refers to the *situation resulting from a violation of international law* and that which includes *the duty to compensate for damages*, generating a framework that could be summarised as follows: "a state may be held internationally

responsible for a wrongful act even if there is no material damage; a state may be held internationally responsible for damage caused even if it has not acted unlawfully" (Drube and Haddaji, 2020).

Both parameters need to be analysed in detail, as does the disclaimer of liability. The legal and legitimate grounds on which international law could be violated should be adapted to the context of the cosmic impact threat. As considered by SMPAG*(Space Mission Planning Advisory Group*):

> "in practice it may be difficult to conduct a comprehensive assessment of whether in a particular case the specific conditions for invoking the circumstances precluding wrongfulness are met, such as whether the threat of an NEO constitutes a 'grave and imminent danger', whether a certain mitigation method is 'the only way' available to safeguard the interests endangered by the potential impact of the NEO and whether the essential interests of other states are seriously harmed" (Drube and Haddaji, 2020).

Furthermore, the exemption of the state from liability for damages caused by the mitigation action could be understood as an incentive for the nation, agency or company carrying out the mission (Drube and Haddaji, 2020). The extreme, but still feasible, case of an imminent threat of mass extinction may require a rethinking of exceptional cases in the interest of the higher and unique good of humanity as a whole. Privileged countries, in this case because they have sufficient technological capacity or resources, would have an ethical duty to mitigate the asteroid's impact by following the maxim that all members of the human community should be treated as equals, with the aim of avoiding structural injustice and seeking relational equality (Heilinger, 2020). Once again, this is an exercise in adjusting the rules to an unprecedented factual situation.

Taking into account all the above criteria, and assuming the differences between climate change and a cosmic impact threat, institutional action to mitigate global warming could serve as a frame of reference to address a transnational problem that requires joint action. Following in the footsteps of the fight against climate change, it would be appropriate to hold international working fora to begin planning planetary defence guidelines. The *International Asteroid Warning Network*, the *Planetary Defence Coordination Office* or the *Space Mission Planning Advisory Group* could lead a conference to discuss the creation of a future planetary defence treaty, paying special attention to the migration phenomenon. Creating spaces for dialogue is essential because, as Schmidt (2018) announces, 'planetary defence gives us the opportunity to think of ourselves as a single interconnected and interdependent species, and we have a responsibility to stop thinking of ourselves as our own enemies, otherwise we will not survive for long'.

10. Conclusions

The experiences of covid-19 and the fight against climate change have highlighted the current human inability to coordinate and prevent catastrophic scenarios. Planetary

defence therefore represents an unprecedented historical and political opportunity to develop new forms of collective action for the defence of human and non-human life on planet Earth. In line with this objective, we have found that the current state of global defence cannot avoid legal-political cooperation to achieve its goals.

In the absence of precedents, it is necessary to highlight the need to reverse the traditional scheme according to which social demands precede law. In a transdisciplinary extrapolation exercise using the scenario method, it is possible to see that uncertainty and cooperation are the main elements in PHO mitigation strategies .

The scientific and prospective analysis of cosmic impacts reveals, first of all, that the threat of collision constitutes a real risk which, because of its potential catastrophic effects, cannot be ruled out on the basis of its low probability. The existential risk implicit in cosmic impacts calls for the principles of precaution and responsibility to defend the conditions of Earth's habitability for future generations.

Secondly, all the scenarios that could occur in the face of a cosmic impact threat (impact warning, no deflection, partial deflection or full deflection) invite reflection on the current techno-epistemic privilege of States with potential mitigation capabilities, which poses both a serious risk to vulnerable States and a danger to the multipolar balance of power at the time of acting out defence strategies .

Thirdly, this work confirms the need to anticipate new contexts, new legal figures and new forms of governance (impact refugees, States without territory, co-sub-governance and virtual governance) as instruments that favour a preventive capacity in the elaboration of regulations, protocols and governmental programmes for national and planetary security.

Only prospective analysis can facilitate the criteria of fairness, equity and proportionality prevailing over privilege and power relations in potentially catastrophic scenarios. In the face of the threat of cosmic impact, the legal-political and bioethical approach concludes that it is necessary to promote the acceptance of restrictions by sovereign States as an indispensable action for coordinated action in accordance with human rights. Ultimately, anticipation becomes the best strategy to guarantee human rights and, ultimately, the survival of humanity.

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