The Legacy of the Dinosaurs: Regulation of Planetary Defence and Near Earth Objects at a global level

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In recent years, Near Earth Objects (NEOs) have caused increasing concerns amongst space scientists and policy makers. While attacks on earth from NEOs are rare, the atmospheric impact of an about 20-meter asteroid near Chelyabinsk/Russia in February 2013, served as a warning that asteroid/comet strikes could seriously threaten humanity[4]. Planetary defence requires strong international co-operation. Despite the

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[4] Secure World Foundation, *Near Earth Objects: Responding to the International Challenge, (*April 2014) p. 2, online: <http://swfound.org/media/170684/SWF_NEOs-Responding_to_the_International_Challenge_2014.pdf> (last visited on 15 January 2018).

initiatives at UNCOPUOS, international law falls considerably short of addressing issues pertaining to the detection and mitigation of hazardous NEOs.

This paper builds upon the "risk society" of Ulrich Beck to propose the creation of a Convention on Planetary Defence. The Convention will address co-operation issues among States and, moreover, establish a Global Fund for Planetary Defence. This Fund will be used for R&D on NEOs, for identifying best practices in deterring potential attacks, and for compensating relevant damages.

It is suggested, that the Convention creates a stand-alone international organisation that operates the Fund to fulfil the aforementioned objectives. Parallels will be drawn from various existing international/national arrangements dealing with disasters, such as terrorism, nuclear and pollution accidents. Yet, it will be demonstrated that the unique risk of NEOs requires a sui-generis solution. Furthermore, liability and recourse issues, including governmental liability for failing to mitigate NEOs strikes will be analysed.

1. The threat of NEOs

1.1. NEOs and PHOs

Near-Earth Objects (NEOs) are planetary debris, created from the formation of our solar system some 4.6 billion years ago. They are mostly asteroids and comets that have been nudged by the gravitational attraction of nearby planets into orbits that intersect that of the Earth or are within 0.3 Astronomical Units.[5]

These celestial bodies are the remnants of the primitive building blocks of the planets, called "planetesimals".[6] In essence, our giant planets were formed by the agglomeration of the planetesimals through several collisions. The asteroids and comets are the left over pieces that remained in orbit around the Sun.

Comets are composed mostly of water ice with embedded dust particles and were originally formed in the cold outer planetary system. Asteroids are rocky or metallic bodies formed in the warmer inner solar system between the orbits of Mars and Jupiter. The composition, density and size of NEOs varies greatly and influences their behaviour when entering the Earth's atmosphere and their reaction to countermeasures.[7]

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[5] Astronomers call the Earth to Sun distance one "Astronomical Unit". See on definition of NEOs *UK Task Force on potentially hazardous Near Earth objects*, Report (September 2000), pp. 11-12, online: <http://www.nss.org/resources/library/planetarydefense/2000-ReportOfTheTaskForceOnPotentiallyHazardousNearEarthObjects-UK.pdf> (last visited on 15 January 2018);

[6] International Academy of Astronautics, *Dealing with the threat to earth from asteroids and comets*, Edited by I. Bekey, p.16, online: <http://swfound.org/media/167468/Dealing_With_Threat_To_Earth_Asteroids_Comets.pdf> (last visited on 15 January 2018)

[7] *Ibid.*

A Potential Hazardous Object is an object in our solar system that passes within 0.05 AU (about 7.5 million km) of Earth's orbit and is large enough, i.e. at least 50 meters in diameter to pass through Earth's atmosphere and cause significant damage on impact.[8]

1.2 The disastrous potential

The odds of a cosmic collision happening during a human life span are significantly limited. Threats arising from potential diseases, natural disasters, or auto accidents are much greater rather than a threat from a NEO impact.[9] In fact, the vast majority of people are oblivious to the prospect of an asteroid or a comet strike.

However, what are very tiny risks for impacts during a human lifetime become certainties on geologic time scales. The increasing understanding of the magnitudes and qualitative features of environmental consequences of impacts of objects suggest that prime attributes of impacts, not duplicated by any other natural processes, are (1) extreme suddenness, providing little opportunity for escape and no chance for adaptation, (2) globally pervasive, and (3) unlimited potential for overwhelming destruction of the life-sustaining characteristics of the fragile ecosphere.[10] Our planet's geological and biological history reveals that a series of destructive impact events have occurred throughout the years. Therefore, in recent years, the issue of planetary defence has become an increasing area of concern amongst the world's space scientists, astronomers and policy makers.

The now widely accepted theory that a NEO strike is responsible for the ultimate destruction of non-avian dinosaurs 65 million years ago, serves as a strong illustration of the disastrous potential such an impact may have. Yet, there are also relatively recent impact events. In 1908 an object, believed to be an asteroid or a comet, exploded over Tunguska River in Russia causing the destruction of 2000 square kilometres of Siberian forest. The overhead detonation was equivalent to the explosive force of a 4 megaton bomb.[11] In 2013, a 17-to 20-meter sized orbiting asteroid entered the atmosphere over Chelyabinsk, Russia and exploded with a force of 500 kilotons. The impact event

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[8] NASA, *Near-Earth Object Survey and Deflection Analysis of Alternatives*, Report to the Congress (March 2007), p. 7, online: <http://www.nasa.gov/pdf/171331main_NEO_report_march07.pdf>, (last visited on 15 January 2018).

[9] Center for NEO Studies (CNEOS), online: <https://cneos.jpl.nasa.gov/about/target_earth.html> (last visited on 15 January 2018).

[10] See details in C. Chapman*., Impact lethality and risks in today's world: Lessons for interpreting Earth history* in C. Koeberl and K. MacLeod. (eds), *Catastrophic Events and Mass Extinctions: Impacts and Beyond*, Geological Society of America Special Paper 356, Colorado 2002, pp. 7–19.

[11] Secure World Foundation, *Near Earth Objects: Responding to the International Challenge,* April 2014 p. 6, online: < http://swfound.org/media/170684/SWF_NEOs-Responding_to_the_International_Challenge_2014.pdf>(last visited on 15 January 2018).

caused injuries to about 1,600 people, with some of them having to be hospitalised from cuts caused by flying materials.[12]

If the Tunguska or Chelyabinsk event had happened over a densely populated area of the world, it would have a catastrophic effect causing the death of millions of people. The fact that these two events happened within the relatively short period of 100 years must serve as a wake-up call for the international community to adopt collective and holistic measures.

2. Methodology of threat mitigation

Unlike the dinosaurs' age, recent developments in space science and technology enable humanity to take preventive action. Scientists can predict whether an object can actually serve as a threat by detecting and categorising NEOs. Technology also allows for the successful prevention or mitigation of a hazardous NEO's impact.

2.1 Detection of NEOs

The detection and tracking of NEOs is the first and fundamental step in designing efficient mitigation strategies. To "know your enemy" enables appropriate planning for its defeat. The orbit of an object defines if, when, and how a strike may occur, as well as the warning times and deflection requirements.[13]

The identification of NEOs can be done with the aid of ground-based or space-based systems.

Ground based systems use large field of optical sensors to scan for NEOs during the night. They cannot function during daylight or twilight and their operation can be interfered by weather, atmospheric turbulence, scattering from moonlight, and atmospheric attenuation. Nevertheless, ground systems, compared to space based ones, are easier to build, verify, operate, maintain and upgrade.[14] NEO identification is currently being achieved by a range of ground instruments. The development of Space Surveillance Telescope[15] is anticipated to bridge gaps in observational coverage by enabling the detection and tracking of small objects in deep space.[16]

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[12] *Ibid*.

[13] Small Bodies Assessment Group (SBAG*), Goals Document* Goal II: Planetary Defense, Draft version 0.5 (26/6/2015), p. 1, online: http://www.lpi.usra.edu/sbag/goals/Goal_II_sbag_pdg_draft0.5.pdf (last visited on 15 January 2018).

[14] NASA, *supra* note 8, p. 8.

[15] It is developed by the Massachusetts Institute of Technology's Lincoln Laboratory for the Defense Advanced Research Projects agency and the U.S. Air Force. For more info see <http://www.darpa.mil/program/space-surveillance-telescope> (last visited on 15 January 2018).

[16] Chile is also developing the Large Synoptic Survey Telescope which is anticipated to be operational in 2020. For more info see <http://www.lsst.org/>(last visited on 15 January 2018).

Space-based systems are capable to scan the entire sky at any given time without any interference[17]. It should be noted, however, that space-based systems are more expensive to develop and they run the risk of launch and deployment failure. Additionally, space-based systems are likely to have shorter lifetime. This may compromise the objectives of a NEO threat mitigation strategy, which may require the tracking of NEOs for extended periods of time.[18]

After identifying the objects, their physical characteristics are determined. This is vital in order to predict the impact risk on Earth, as well as to calculate the object's response to a mitigation mission. The characterisation of an object involves the determination of its composition, size, shape and rotation rate[19]. Radar observation is a powerful tool for characterising NEOs.

2.2 Prevention or mitigation of the impact

The most effective method to avert a NEO impact on Earth is to change its orbit. This can be achieved by using energy to change its velocity, so that it arrives sooner or later than Earth at the point of intersection.[20] With advance warning of many years, a change in the velocity of a NEO by only few centimetres per second can successfully cause the object to miss the Earth[21]. Several techniques have been proposed over the years to shift a NEOS trajectory.

One such technique is the *kinetic impactor*, according to which a NEO is deflected after an impact by a spacecraft, which causes a slight shift of the orbit. In essence, the spacecraft hits the NEO at high relative velocity, so that the object's speed immediately changes because of the energy and momentum exchange.[22] Another technique is the *gravity tractor*, in which a spacecraft flies alongside a NEO for a certain period of time, gradually pushing it off course through the small gravitational attraction between the two. Moreover, the *blast deflection* technique requires the use of nuclear explosives near the NEO causing its outer layers to evaporate, changing in that way its trajectory. Non-nuclear explosives can also be used to perform small or medium pushes to the NEO.[23]

For the successful prevention or mitigation of a menacing NEO impact, time is of essence. In order to be able to plan and deploy a successful deflection mission, three elements are necessary: (a) sufficient advance warning of a minimum 10-15 years, (b)

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[17] Some of the current space based instruments are NASA's NEOWISE and Canada's NEOSSAT – see infra para. 3.2.

[18] NASA, *supra* note 8, p.9.

[19] National Aeronautics and Space Administration (NASA), Planetary defence, online:< https://www.nasa.gov/planetarydefense/faq>

[20] International Academy of Astronautics *supra* note 6, p. 7.

[21] *Ibid,* p.8.

[22] International Academy of Astronautics, *supra* note 6, p. 8.

[23] Secure World Foundation, *supra* note 11, pp. 13-14.

deflection capability and (c) an international decision-making mechanism.[24] These three elements enable the deflection campaign to proceed timely, so that the predicted impact is prevented.

When preparing to prevent an impact, the communication with the public is also of utmost importance. A coordination plan should be developed detailing the nature of the threat, evacuation activities and instructions to the public. The aftermath of the Indian Ocean Tsunami and hurricane Katrina revealed that only realistic planning and preparation can minimise the chaos that is likely to occur.[25]

3. Current efforts for threat mitigation

Currently, efforts for NEO threat mitigation are undertaken mainly by international organisations and individual States. At the same time, private initiatives have been developed.

3.1 International organisations

3.1.1. United Nations

The United Nations (UN) have been undertaking significant work on NEOs, following the report of the Third United Nations Conference on the Exploration and Peaceful Uses of Outer Space (UNISPACE III) in 1999,[26] which encouraged the improvement of international cooperation on this issue. As a follow-up to this report, the UN Committee on the Peaceful Uses of Outer Space (COPUOS), created the Action Team on Near-Earth Objects, also referred to as Action Team 14 (AT-14),[27] which comprises scientific and space agency delegates from interested States and non-governmental organisations.

In 2013, the UN General Assembly approved a series of concrete measures,[28] to protect the Earth against hazardous NEOs. This important milestone resulted from a series of lengthy discussions in the UN COPUOS and AT-14. The measures approved involve,

[24] Association of Space Explorers, *Asteroid Threats: A Call for Global Response* (25 September 2008), p.14 online: <http://www.space-explorers.org/ATACGR.pdf> (last visited on 15 January 2018).
[25] International Academy of Astronautics, *supra* note 6, p.9.
[26] Report of the Third United Nations Conference on the Exploration and Peaceful Uses of Outer Space, Vienna, 19-30 July 1999 (18 October 1999), A/CONF.184/6, online: <http://www.unoosa.org/pdf/reports/unispace/ACONF184_6E.pdf >(last visited on 15 January 2018).
[27] Report of the Committee on the Peaceful Uses of Outer Space, Fifty-sixth Session (2001), A/56/20, online: http://www.unoosa.org/pdf/gadocs/A_56_20E.pdf (last visited 15 January 2018).
[28] Resolution adopted by the General Assembly on 11 December 2013 (16 December 2013), A/RES/68/7520, online: http://www.un.org/en/ga/search/view_doc.asp?symbol=A/RES/68/75 (last visited on 15 January 2018).

inter alia, the creation of an International Asteroid Warning Network (IAWN) and a Space Mission Planning Advisory Group (SMPAG).[29]

3.1.1.1 International Asteroid Warning Network

The IAWN is tasked with the coordination of an international group of organisations involved in detecting, tracking, and characterising NEOs. IAWN also acts as an international coordination service for processing alerts about possible threats. Furthermore, IAWN will develop a strategy to assist Governments in the analysis of asteroid impact consequences and the planning of mitigation responses. Currently, there are eight official signatories to the IAWN Statement of Intent.[30]

3.1.1.2 Space Mission Planning Advisory Group

The SMPAG is comprised of voluntary representatives of Member States with space agencies. Its purpose is to prepare an international response to a NEO impact threat by exchanging information, promoting collaborative research and mission opportunities, as well as planning activities for NEO threat mitigation.[31]Since 2016, as per the General Assembly resolution 71/90, the United Nations Office for Outer Space Affairs serves as the permanent secretariat to SMPAG.[32]

3.1.2. European Union

In the framework of the European Union, the European Commission has funded the NEOshield project which aims at improving our knowledge on NEOs physical characteristics and investigating the effectiveness of asteroid threat-reduction techniques. The NEOshield project was undertaken by research institutes, universities and industrial partners in Germany, France, the United Kingdom, Spain, and in the U.S. and Russia. Since 2015, the work continues with NEOshield-2 which aims to

[29] These measures were initially proposed by the Association of Space Explorers (ASE) in their report, *Asteroid Threats: A Call for Global Response* (2008), see *supra* note 24. ASE recommended that the UN should support asteroid warning and information sharing, mission operations planning as well as authorization and oversight functions. The report was submitted to UN COPUOS in 2009 for consideration and subsequent action. The UN COPUOS Scientific and Technical Subcommittee, its NEO Working Group, and AT-14 discussed and refined these proposals.

[30] For more info see United Nations Office for Outer Space Affairs, online: <http://www.unoosa.org/oosa/en/ourwork/topics/neos/iawn.html> (last visited 15 January 2018)

[31] See SMPAG Terms of Reference, online: http://www.cosmos.esa.int/web/smpag/terms-of-reference-v0 (last visited on 15 January 2018).

[32] See United Nations Office for Outer Space Affairs online: http://www.unoosa.org/oosa/en/ourwork/topics/neos/smpag.html ((last visited 15 January 2018))

investigate in more detail technologies critical to NEOs deflection missions as well as to refine NEOs characterization.[33]

3.1.3. European Space Agency

The European Space Agency (ESA) has developed a multi-segment Space Situational Awareness (SSA) Programme. Its aim is to detect, predict, and assess the risk to life and property due to man-made space debris objects, harmful space weather and potential impacts of NEOs. The objective of SSA's Near-Earth Object Segment is to raise awareness of the current and future position of NEOs in relation to Earth, to estimate the likelihood of impacts, to assess the consequences of any possible impact and to develop NEO deflection methods.[34] The data collected from telescopes is retrieved by the NEO Coordination Centre (NEOCC). In the event of a high risk impact predictions, the data will be cross-checked with NASA's SENTRY system which is operated by the Jet Propulsion Laboratory (JPL).[35]

Moreover in 2014, Philae, a robotic lander, successfully achieved the first ever landing on the surface of a comet, as part of ESA's Rosetta mission. Until the end of the mission in 2016, Philae took images which will assist scientists to study and learn more on the composition of comets and on their role in the evolution of the Solar System. This knowledge will significantly help in the planning of threat- mitigation techniques.

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[33] See Neoshield 2 Project, online: <http://www.neoshield.eu/science-technology-asteroid-impact/> ((last visited on 15 January 2018).

[34] For more info see European Space Agency (ESA), online: <http://www.esa.int/Our_Activities/Operations/Space_Situational_Awareness/Near-Earth_Objects_-_NEO_Segment> (last visited on 15 January 2018).

[35] See European Space Agency (ESA), online: <http://www.esa.int/Our_Activities/Operations/Space_Situational_Awareness/Near-Earth_Objects_-_NEO_Segment> (last visited on 15 January 2018)

[36] See Neoshield 2 Project, online: <http://www.neoshield.eu/science-technology-asteroid-impact/> ((last visited on 15 January 2018).

3.2. Individual States

3.2.1. United States of America

The US National Aeronautics and Space Administration (NASA) maintains a leading role in the prevention of NEOs impact. Planetary defence has been gaining particular attention in the US and it is within the nation's top –tier space policy issues.[37]

Already in 1998, the US Congress directed NASA to locate at least 90 percent of all NEOs with a diameter of 1 km or greater within the period of 10 years. NASA and its partners managed to achieve this goal in 2011. Additionally, NASA's Authorization Act of 2005,[38] set a far more challenging task for NASA, i.e. to detect, track, catalogue, and characterise 90 percent of all NEOs with a diameter of 140 meters or greater by 2020.[39]

The vast majority of NEO discoveries have been the result of NASA-supported ground-based telescopic surveys including the Catalina Sky Survey (CSS) and Spacewatch near Tucson, Arizona; the LINEAR project near Socorro, New Mexico; Pans-STARRS1 on Haleakala, Maui, Hawaii; LONEOS near Flagstaff, Arizona; and the NEAT project run by NASA/JPL. Also the NEOWISE project has been reactivated to discover and characterise asteroids using a near-infrared space telescope in an Earth polar orbit.[40] The technological progress and the appropriate funding has enabled increased discovery of NEOs over the last years. This is demonstrated by the large NEO catalogue maintained by the Minor Planet Center (MPC) in Cambridge, Massachusetts, which collects and distributes data to the international community.[41]

In 2016, NASA established a Planetary Defense Coordination Office (PDCO), with the mission to safeguard the early detection of potentially hazardous objects – asteroids and comets with a size capable to reach Earth's surface and whose orbits can bring them within 0.05 Astronomical Units of Earth. The PDCO uses data from projects supported by NASA's Near-Earth Object (NEO) Observations Program.[42]

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[37] See National Space Policy of the United States of America, (28 June 2010) p. 4, online: <http://history.nasa.gov/national_space_policy_6-28-10.pdf> (last visited on 15 January 2018) and NASA Strategic Plan 2014, p.8, online: http://www.nasa.gov/sites/default/files/files/FY2014_NASA_SP_508c.pdf (last visited on 15 January 2018).

[38] Also known as the George E. Brown, Jr. Near-Earth Object Survey Act.

[39] Section 321 of the NASA Authorization Act of 2005 (Public Law No. 109-155), online: <http://www.gpo.gov/fdsys/pkg/PLAW-109publ155/pdf/PLAW-109publ155.pdf> (last visited on 15 January 2018). The programme, however, has been unsuccessful so far, owing to administrative and budget restraints – see http://phys.org/news/2014-09-nasa-asteroid-defense-falls-short.html (last visited on 15 January 2018).

[40] See CNEOS, NEO Search Programme, online <http://neo.jpl.nasa.gov/programs/intro.html> (last visited on 15 January 2018).

[41] Secure World Foundation, *supra* note 11, p.8.

[42] For more information see NASA, Planetary Defence Coordination Office, online: <https://www.nasa.gov/planetarydefense/overview> (last visited on 15 January 2018)

3.2.2. Canada

In 2013, Canada launched the Near-Earth Object Surveillance Satellite (NEOSSat). It is the world's first space telescope dedicated to detecting and tracking asteroids and satellites. It performs a circle of the globe every 100 minutes, scanning space near the Sun for hazardous asteroids. Thanks to its location, it can spot asteroids which are difficult to track with ground telescopes and it can operate 24/7 without any limitations.[43]

3.2.3. Russian Federation

The Russian Federation is working on an SSA programme to detect, inter alia, hazardous NEOs. The International Scientific Optical Network (ISON), a growing international network of small telescopes linked together, is a major contributor in establishing an SSA programme. Additionally, Russia also operates several radar telescopes for characterization of identified asteroids, while planning to build several new ones. Russia is also looking to build and launch a space-based NEO telescope by 2021.[44]

3.2.4 Japan

Japan has successfully completed the Hayabusa mission, which collected samples from a small asteroids named Itokawa and returned them to Earth in June 2010. In 2014 the Japan Aerospace Exploration Agency (JAXA) successfully launched its Hayabusa2 mission to rendezvous with an asteroid, land a small probe plus three mini rovers on its surface, and then return samples to Earth. NASA and JAXA are cooperating on the science of the mission.[45]

3.3 Private initiatives

The Spaceguard Foundation, is a private, non-profit international organisation, set-up in 1996 and based in Italy. Its objective is to study, discover and observe NEOs and to protect the Earth environment against NEO impact threats.[46]

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[43] For more info see Canadian Space Agency, online: <http://www.asc-csa.gc.ca/eng/satellites/neossat/> (last visited on 15 January 2018).

[44] Secure World Foundation, *supra* note 11, p. 8-9.

[45] See NASA Science Beta, Japan Launches Asteroid Mission, (4 December 2014) online: http://science.nasa.gov/science-news/science-at-nasa/2014/04dec_hayabusa2/ (last visited on 15 January 2018).

[46] See The Spaceguard Foundation, online: <http://spaceguard.rm.iasf.cnr.it/SGF/INDEX.html >(last visited on 15 January 2018).

The *Emergency Asteroid Defence Project* (EADP) is a Danish non-governmental organisation, which includes scientists, engineers and other interested persons trying to raise $200k on crowdfunding website Indiegogo, to continue its research into hypervelocity asteroid intercept vehicles (HAIVs) designed to deflect or disperse asteroids and comets with only a few days' warning.[47]

3.4 Evaluation of current efforts

All these efforts move to the correct direction and represent significant steps for alleviating the threat posed by NEOs. Nevertheless, they are inefficient, because they lack coordination, appropriate funding and technical resources. In this regard, one could mention the 2014 Report in NASA's Inspector General[48] which states that due to administrative and budget restraints as well as organisational weaknesses, NASA will not be able to detect, track, catalogue, and characterise 90 percent of all NEOs with a diameter of 140 meters or greater by 2020 as required by the NASA's Authorization Act of 2005.

Planetary defence is a global and complicated issue and at the same time crucial for the well-being and the survival of our species. Therefore, efforts should be organized at a global scale.

4. Proposal for an international approach

4.1 Background: Risk perception and risk management

Eric Posner, writing in 2004, argued that the need for organising a planetary defence system is underestimated despite the catastrophic potential of NEOs.[49] The reasons behind this trend are "… a combination of the science-fiction label that has become attached to the menace, the lack of any history of casualties being caused by asteroids…, and the sense that concern with such low-probability dangers would be a distraction from the struggle against international terrorism".[50]

His findings should not come as a surprise to the scientific community. A survey, that took place in 1992 in the USA, revealed "modest support for detection efforts but considerable opposition to the use of weapons in space, even to deflect a threatening asteroid. The survey respondents indicated a strong preference for collecting more data on the risk before developing a defence system".[51] This preference run (partially)

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[47] See Emergency Asteroid Defence Project, online: <http://eadproject.com/> (last visited on 15 January 2018).

[48] NASA's Efforts to Identify Near-Earth Objects and Mitigate Hazards, Audit report (15 September 2014) online: <https://oig.nasa.gov/audits/reports/FY14/IG-14-030.pdf> (last visited on 15 January 2018).

[49] R. Posner, *Catastrophe. Risk and response* (OUP 2004), pp.28-29.

[50] *Ibid.,* p. 250.

[51] P. Slovic, "Perception of risk from asteroid impact" in P. Bobrowsky and H. Rickman (eds.) *Comet/Asteroid impacts and human society* (Springer 2007), pp. 369, 379.

against the perception among the same respondents that NEO risks were "extreme with regard to being unknown to scientists and the public, distant in time (non-immediate), uncontrollable and catastrophic".[52]

What both works reveal is the central role that risk perceptions play in the regulation of risk events. In the words of Ulrich Beck "the *perception* of threatening risks determines thought and action" in modern risk societies.[53] As such, the following paradox has been created. The quest for safety against risk events which "transcend traditional boundaries of time and space" preoccupies the Western societies.[54] Yet, this quest is not necessarily guided by probabilistic risk analysis, but is very much influenced by the (fears and) reactions of the public to (the threat of) risk events.

As such, the developer of a regulatory system addressing catastrophic risks is required to manage social perceptions, as much as real risks. This is not an easy task, as it only takes the occurrence of a risk event to lead to, what Ulrich Beck describes as, the "the de-bounding of risk perceptions and fantasies".[55] A collision between a NEO and the Earth that causes death and property damage in a large scale, is a first-rate opportunity for the media, provided Earth is saved from annihilation, to amplify its consequences by creating a (more or very) dramatic version of reality. Similar past events have not caused such reaction either because they took place before living memory or they were near-misses in the sense that they resulted in relatively limited damages - at least compared to what could have been.[56]

From the legal standpoint, the most important part of this amplification process will be the search for culpable parties among those who were in charge of managing such risks. One might argue that this search for culpability is a far-fetched scenario in the case of NEOs, as i) a collision between an asteroid and the Earth cannot be attributed to technology;[57] and ii) the scientists dealing with their detection/mitigation seem to enjoy a high degree of credibility by the media: "apparently the media had treated their activities in a positive light and had not interpreted their public statements as particularly ill-founded or self-serving".[58]

However, history suggests that media are quick to change attitudes vis-à-vis scientists and risk managers in the aftermath of risk events. In their attempt to capitalise on the "impact factor" (no pun intended) of risk events, they construct them as the result of moral failures of risk managers.[59] Risk events, man-made or natural, are the result of their personal traits and mental processes, such as forgetfulness, inattention, poor

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[52] *Ibid.*

[53] U Beck, *World risk society* (Polity Press 1999), p. 135.

[54] G. Mythen, *Ulrich Beck: A critical introduction to the risk society* (Pluto Press 2004), p. 22.

[55] U Beck, *supra* note 53, p. 44.

[56] See *supra* para. 1.2.

[57] R. Posner, *supra* note 49, p. 24.

[58] P. Slovic, *supra*, note 51, p. 380.

[59] T. Horlick-Jones, "Modern disasters as outrage and betrayal"(1995) 13 International Journal of Mass Emergencies and Disasters, pp. 305, 311.

motivation, carelessness, and recklessness.[60] For how long this perception lasts depends on the gravity of the risk event in question and the post-event reactions of the industry and States.

The fact that the collision of an asteroid with the Earth is a natural event is irrelevant to this construction. The more accurate the identification of NEOs and the avoidance of collisions becomes, the more vulnerable to a legal action the bodies in charge will be. As the actual risk-creator is absent, the search for culpability moves to the human actors who allegedly facilitated the collision by missing the NEO or did not take the appropriate mitigating action as a result of a judgment error. The actions filed against National Oceanic and Atmospheric Administration (NOAA) in the aftermath of the Indian Ocean earthquake and tsunami in 2004, surprising and frivolous as they were, demonstrate the issue at hand.[61] The search for culpability is not restricted to the risk creator but, in its absence, extends to those in charge of monitoring the risk situation and issuing warnings about imminent risk events.

As a result, any future regulation of NEOs should not be limited on their quantitative aspect, but also embrace their qualitative elements in equal measure. This will only be achieved if the scheme has the following dual scope.

Firstly, it should facilitate the advancement of R&D on the identification and mitigation of the risks associated with NEOs. The overarching aim in this part is to satisfy the demand for collecting more data on the actual risks posed by NEOs, setting accurate early warning systems, identifying remedial actions at a global level and creating emergency response protocols in cases of accidents. Currently, the scientific community has a much better understanding of the risks posed by NEOs compared to 1992 when the survey was published.[62] This development has been achieved despite the limited funding and the persisting doubts about the credibility of the threat posed by NEOs. The results demonstrate that the regulators cannot afford to ignore the said risks anymore. Not surprisingly, the international space community has started to discuss the potential and the form of a future international regulation. The creation of the IAWN and the SMPAG is a step to the right direction.[63] Yet, it shall be treated as the first step towards a comprehensive international regulation of NEO risks.

Secondly, it should deal with the legal aftermath of an accident. The overarching aim in this part is to create a system that contains the "de-bounding of risk perceptions" and its ensuing effects by separating culpability from compensation. It is to be hoped that this distinction would create incentives for cooperation and trust-building among the

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[60] J. Reason, "Human error. Models and management" (2000) 172 West J Med, pp. 393-396.

[61] For details on the history of the claims see A. Ito, *Legal aspects of satellite remote sensing* (Martinus Nijhoff 2011), pp. 191-194 and University of Nebraska-Lincoln's Programme on Space and Telecommunications Law, "Legal Aspects of NEO Threat Response and Related Institutional Issues. Final Report" (9 February 2010), para. 4.3, online: Secure World Foundation, online: <http://swfound.org/media/40426/legal_aspects_neo_response_institutional_issues_final_report.pdf>(last visited on 15 January 2018).

[62] *Supra* Ch. 3.

[63] *Supra* para.3.1.1.

various actors involved. Any alternative would lead to adjudication and blameworthiness that will inevitably erode the fundamental aim of such system, namely the effective protection against the risk of NEOs.

The debate over the structure of a scheme dealing with NEOs is a nascent one with many avenues to explore. Understandably, the spatial constraints of this publication do not permit an all-inclusive analysis. Yet, the aim of this part of the paper is to contribute to the debate by providing "food for thought" to the drafters of a future scheme.

4.2 Policy considerations in establishing the Fund

Very few States have the technical capability to manage the risks posed by NEOs. They lead the way in R&D, yet they are required to work within the framework of the fundamental principles of space law, namely the use of outer space for the benefit of humankind and in the interest of promoting international co-operation and understanding, taking into consideration the interests of all State Parties to the Outer Space Treaty.[64] These principles call for the creation of a scheme that has the interests of humankind at its centre, ideally involving all States in the decision-making process; with arguably the most pressing issue being the establishment of a duty of "international co-operation and assistance on planetary defence".[65]

At the same time, the creation of a scheme dealing with NEOs at a global level would be a challenge for regulators from a risk management perspective unlike anything seen until today. The reason of this challenge is not necessarily the catastrophic potential of NEOs. It is the *sui generis* nature of such system that is required to have an all-inclusive risk management role: provide financial support for developing technology to identify and mitigate NEOs (precautionary risk management); decide on the appropriate course of action in the case of detecting, early enough, that an NEO is in a collision path with the earth (proactive risk management); and deal with the aftermath of a collision in terms of employing the necessary emergency and investigation protocols, making funds available for funding the rescue efforts and compensating victims (reactive risk management).

Such a tripartite structure is not common in the international or national field. Most schemes dealing with risk events handle (part of) their reactive risk management function by acting *in lieu* or on top of the cover provided by commercial insurers. The common denominator behind the International Civil Aviation Compensation Fund (ICACF-aviation terrorism),[66] the International Oil Pollution Compensation Funds

[64] Arts I, III and IV of the 1963 Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies.

[65] The analysis of this duty is outside the scope of this paper.

[66] The ICACF is set up by the 2009 Convention on Compensation for Damage to Third Parties, Resulting from Acts of Unlawful Interference Involving Aircraft. As of 4 August 2015 the Convention has not entered into force.

(IOPC funds - oil pollution at sea),[67] the Criminal Injuries Compensation Scheme (CICS - violent crime in Great Britain), the Motor Insurers' Bureau (MIB - road accidents in the UK) and the schemes for the risks posed by nuclear power plants [68] is that they "socialise" the financial burden of relevant risk events. This is achieved i) by creating a system where the various commercial actors involved in the relevant risk-generating activity (including consumers in ICACF and (indirectly) in MIB) pay out admissible claims, most often but not necessarily, via a Fund set up for this purpose (ICACF, IOPC, MIB); ii) by creating a clear obligation for States to foot the bill of the risk event on the basis of policy reasons (CICS); or iii) by combining the two, creating a system where the contributions towards compensation are coming from both commercial actors and governments (nuclear power plant risks).

Understandably, one might wonder why such a "light" structure is not recommended in the case of NEOs.

One reason is political and has been one of the drawbacks of ICACF: depositing a few billion dollars in an international organisation to deal with the effects of a low probability risk event does not appeal to contributors, especially in times of austerity. The most often utilised schemes cover either high(er) probability risk events (IOPC funds, MIB), are set up and administered by domestic governments based on their policy choices (CICS), or support industries that are considered desirable despite their potential for catastrophe (nuclear power plants). In that respect, it is expected that the establishment of a compensatory-only scheme for NEOs will go nowhere. It will face reluctance from most governments to commit funds for dealing with the aftermath of a risk that might never materialise in the lifetime of their voters. This is so, of course, unless a catastrophic event involving NEOs takes place.

Secondly, the establishment of a compensation-only fund will address the arguably less relevant (at the moment) issue of recovery. That will leave in a state of flux the most pressing issues of funding, which are the loss-prevention research and finding avenues of consensus in managing the relevant risks. At the same time, such choice will fail to lay the groundwork for creating a co-operative decision-making system, as it will be limited to (a small part of) the post-accident phase of NEO-related events. In essence, all that it will do is to postpone the creation of a framework that will reconcile issues of sovereignty with best practices of risk management formulated by the few technically-capable States. Can this be interpreted as giving permission to the said states to proceed

[67] The Funds are set up by the 1992 International Convention on Civil Liability for Oil Pollution Damage, the 1992 International Convention on the Establishment of an International Fund for Compensation for Oil Pollution Damage and the Protocol of 2003 to the 1992 International Convention on the Establishment of an International Fund for Compensation for Oil Pollution Damage.

[68] See the 1960 Paris Convention on Third Party Liability in the Field of Nuclear Energy, as amended by the Additional Protocol of 28th January 1964, by the Protocol of 16th November 1982 and the 2004 Protocol to amend the 1960 Paris Convention as amended**.** See also the 1963 Convention supplementary to the 1960 Paris Convention as amended. Finally see the 1963 Vienna Convention in Civil Liability for Nuclear Damage, as amended by the 1997 Protocol to amend the 1963 Vienna Convention and the 2007 Vienna Convention on Supplementary Compensation for Nuclear Damage.

with their endeavours in a unilateral manner? Probably not; yet, it will certainly steadfastly ignore the elephant in the room.

Similarly, suggestions to create "light" structures by focusing on specific legal issues, such as the use of nuclear weapons to prevent collisions,[69] shall be dismissed. They contribute minimally to the main aim of identifying the risks and enhancing our defences at a global level. At the same time, they are, on their own, a "hard sell" to governments which feel that they have limited space for compromise when the negotiating agenda is so restricted.

In that respect, it is submitted that the most appropriate way forward is to set up a holistic scheme that will regulate all three risk management phases of NEO risks. Setting up such a scheme might take longer than opting for a fragmented, piecemeal framework. Yet, its creation is expected to satisfy all relevant interests, legal and operational, provided it is designed in a manner that promotes flexibility in decision-making. The flexibility is essential in order to counteract one of the main arguments against such grand design, namely that it will impair the effectiveness of mitigating actions and emergency responses: "…states [with technical capabilities] might resent detailed interference with an actual mitigation campaign, and more likely still might not accept being ordered to act by an international body, even if it would be a Security Council of which they themselves might be members" .[70]

However, this is a misplaced argument. The examples of organisations such as ICAO and, to a lesser extent, IMO demonstrate that the creation of international legal norms via international organisations can be beneficial to the development of global industries that rely on R&D. Admittedly, the said international organisations do not have as broad a mandate as the one suggested in this paper. Yet, they have proven that collective decision-making can add value to the regulated activity. In that respect, one should not overlook the practical and educational value of having an international forum dealing with the entire risk management process. Creating such a hub is expected to stimulate a multidisciplinary dialogue early in the process of drafting best practices and legal norms, making them as fit for purpose as possible. The importance of such practice cannot be overstated as it will be beneficial to the fast(er) development of our planetary defence system and will fit like a glove with the philosophy of communality of space.

What follows is a few ideas on the structure of a future scheme on the management of the risks posed by NEOs on the basis of our analysis so far.

4.3 Creation of an international planetary-defence organisation

[69] See H. Mayer, "Is a special legal regime for planetary defence measures necessary?" (6 June 2015), online: International Academy of Astronautics http://iaaweb.org/iaa/Scientific%20Activity/conf/pdc2015/IAA-PDC-15-06-06po.pdf (last visited on 15 January 2018).

[70] Nebraska legal report, *supra* note 61, para. 6.8.

It is recommended that the scheme is set up by means of an international treaty (the Treaty) that will be the constitution of an international organisation (the Organisation) with its own legal personality and system of governance. This way it will enjoy independence from existing schemes, its structure will reflect the idiosyncrasies of NEOs and a message will be given that the international community takes the relevant risks seriously.

4.3.1 Structure

It is important that that this Organisation deals with both the quantitative and the qualitative aspect of the risk of NEOs. To achieve this, it is essential to have a structure that i) facilitates collective decision-making even in periods of crisis; ii) provides for the adoption of the necessary legal norms and best practices protocols; and iii) provides funding for research, prevention and crisis management, including the settlement of claims.

It has been rightly suggested that the decision-making process at the highest level shall be based on the paradigm of the relationship between the UN Security Council and the UN General Assembly. This is so because "[i]n practice…the result will be individual or multilateral action by sovereign states acting within the confines of the mandate [given by the Council] but otherwise making their own decisions as to how to apply force".[71] Correct as this recommendation is, this relationship shall be replicated in the context of the new Organisation. In that respect the Organisation shall consist of a Council and an Assembly. The Council shall be entrusted with maintaining international safety against the threat of NEOs and the Assembly shall give legitimacy to its decisions, keeping a watchful eye on the interests of mankind.

Nevertheless, the new scheme should not fit into the confines of the UN for the following two reasons. One reason that has already been advanced is that the replication will permit a restructuring of the membership of the new Council to represent the space capabilities of the State-Parties.[72] An additional reason can be identified: the creation of an independent organisation would facilitate the creation of legal norms and best practices focusing on the risk management of NEOs. This can be achieved by incorporating organs similar to the IAWN and SMPAG ("IAWN" and "SMPAG") into the structure of the Organisation, making them (with the necessary adjustments in terms of membership and mandate) the powerhouses of the Organisation. They can play the role of the Air Navigation Commission of ICAO where a group of nineteen aeronautical experts are responsible for proposing to the ICAO Council amendments to the existing technical Annexes to the Chicago Convention, as well as the creation of new Annexes.[73] "IAWN" shall be focusing on the precautionary risk management phase and "SMPAG"

[71] *Ibid,* para. 6.7.

[72] *Ibid*., para 6.13.

[73] Articles 56 and 57 of the Convention on International Civil Aviation, signed at Chicago, on 7 December 1944 (Chicago Convention).

on the proactive/reactive phases. They would consist of experts in their respective fields and one of their aims would be to draft relevant legal norms and best practices. Such norms would be recommended for adoption to the Council, which upon approval would submit them to the State-Parties. With them being finally approved, if the required number of State-Parties do not file objections against them within the time-frame prescribed by the Treaty.[74]

It is important to note that the "IAWN" and "SMPAG" via subsidiary organs and national space agencies shall undertake a public awareness campaign about NEOs. Such a campaign shall inform the public about what NEOs are, the risks they pose to our life and the various mitigation methods that can be used to prevent collisions. The long-term aim of such campaign would be to persuade the public to support the funding for managing the risks of NEOs and at the same time to educate it to see through the biases of media in reporting risk events.

4.3.2 Contributions to the Fund

With respect to funding, it is important that the Treaty sets up a Fund ("the Fund").The Fund shall be administered by the Secretariat that is headed by a Director. The Director shall be responsible for the management of the Fund and in particular its compliance with internal and external financial regulations. (S)he will also be in charge of all the functions of the Secretariat. The Secretariat will have a dual role. It will assist the Director in the management of the Fund by providing financial and legal expertise and at the same time provide administrative support to the Assembly and the Council.

For building up the capacity of the Fund, it is necessary that all State Parties to the Treaty automatically become parties to the Fund and make the necessary financial contributions. The Fund shall not have a compensatory-only scope. Instead, it shall provide financial support to the State-Parties engaged in NEO-related research, cover the costs of mitigation campaigns taking place under the remit of the organisation, and be the exclusive source of compensation to victims of collisions, provided the loss occurs in the territory of a State-Party. For humanitarian reasons, the Treaty might make provision for non-State Parties to use the Fund in case of damage in their territory, upon approval of the Assembly and provided they commit to becoming Parties to the Treaty.

It is recommended that the Treaty makes **no pre-allocation** of the funds to each of the three aims of the Fund. The funds could be allocated on a yearly basis by the Council to reflect the risk profile of NEOs and the state of research, always leaving a reserve to deal with a crisis. This decision of the Council shall be taken following a joint recommendation from the "IAWN" and the "SMPAG". This arrangement is expected to give the necessary flexibility to put the funds in the best possible use in terms of managing the risks of NEOs on any given year. It is suggested that a more flexible decision-making process shall be adopted on how to spend the allocated funds: the Assembly, having agreed on broad guidelines, shall delegate the decisions on which

[74] See also Article 90 of the Chicago Convention.

projects to be funded to the "IAWN" and "SMPAG". This delegation of authority is justified on the basis that the role of "IAWN" and "SMPAG" will be to have a hands-on role with respect to the three phases of NEOs management. Still, an emergency reallocation procedure shall be provided, in case the funds of the reactive risk management phase are not sufficient to cover the exposure of the Organisation to a risk event occurring in the midst of the year.

The rate of contributions shall be decided by the Assembly. It can be based on a number of factors, such as the size of the country, its expenditures on research and whether it provides means for mitigating NEOs at a global level. The idea behind this suggestion is that bigger countries have a higher probability of being hit by an asteroid. At the same time, countries with no or little technical capability might be requested to offer more funds to support the ones that play an active role in the management of the risks. Admittedly, this is an area that the Organisation shall keep an open mind: if commercial activities ever take place in Space in mass, a "saving the humankind" levy might be imposed on their organisers.

4.3.3 The function of the Fund

In case a NEO either requires the launch of a mitigation campaign or causes personal injuries or property damage in a State-Party, the role of the Fund would be to contribute towards the cost of the campaign and/or the compensation of the victims. In that respect, the following three issues shall be addressed:

4.3.3.1 International mandate for action

Firstly, it has been rightly argued that the sharing of such costs by the international community should depend on the mitigation campaign taking place "within a mandate established by a concurrence of General Assembly and Security Council actions";[75] without such mandate, the cost shall fall onto the State that took the unilateral action.[76] Harsh as this might sound, it is an important provision in order to establish the authority of the Organisation and make planetary defence a truly international attempt. Having said that, it is equally important that an emergency procedure is established to deal with situations that require immediate response leaving no time for seeking such mandate. That might provide for the urgent convening of the Council or for giving the mandate to "SMPAG" in advance to initiate the mitigation procedures subject to the urgent approval of the Council. An alternative already suggested is to adopt a procedure along the lines of the Emergency Special Sessions of the UN General Assembly.[77] This procedure shall become part of the Treaty, yet its effectiveness might be limited by the fact that only very few States have the capability to operate mitigation campaigns.

[75] Nebraska legal report, *supra* note 61, para. 6.9.

[76] *Ibid*., para. 6.10.

[77] *Ibid*., para. 6.6.

Unless they are on board, there is little that can be done by the rest of the international community. However, the establishment of a duty of "international co-operation and assistance on planetary defence" has the potential to change the dynamics of this relationship.

4.3.3.2 Liability and risk management

Secondly, grave doubts have been expressed about the suitability of the 1971 Liability Convention and/or other existing international norms to deal with questions of State liability that might arise in the process of managing NEOs risks.[78] The drafters of the Treaty shall take the opportunity to end once and for all this debate by waiving the liability of the States participating in the research of NEOs and/or undertaking the mitigation/emergency response to a risk event. Such a waiver shall be broad enough to cover both the failure to warn and the failure to adequately mitigate the relevant NEO-risk/manage the emergency response. The necessary condition for granting such immunity shall be for the States in question to operate within the remit of the Organisation and comply with the provisions of the Treaty. It has been suggested that the waiver shall be granted upon the additional condition that the response of the State in question was "a *bona fide* effort at NEO threat mitigation".[79] Identifying what constitutes "*bona fide* effort" shall be approached with caution, because it has the potential to invite litigation from the back door: it needs to be formulated clearly and precisely, avoiding legal terms, such as wilful misconduct or even reasonableness, that are subject to different interpretations from various legal systems.[80] Admittedly, a wide immunity will face the reluctance of some States. Yet, it is the best way forward in setting the basis for a holistic system of planetary defence that aims to serve the international community against a natural risk.

In essence, the Fund shall be responsible for settling the level of compensation paid to the victims, detaching the risk management process from questions of blameworthiness. The Treaty shall give exclusive jurisdiction to the Fund to settle claims in the aftermath of the risk event, with their negotiations performed by claim managers employed by the Fund as part of the "SMPAG". In that respect, particular care shall be taken when identifying the types of damages to be recovered. The drafters might opt for a conservative approach, limiting them to death, personal injury, and property damage that are the direct consequence of the risk event. A liberal approach, which is witnessed in recent treaties dealing with the risks of nuclear power plants, is to identify the instances of recoverable economic losses, such as economic loss arising from personal or property damage, including the cost of restoring the damaged property, the loss of

[78] *Ibid.,* paras. 4.1 ff.

[79] *Ibid.,* para 4.29.

[80] For a review of the varying interpretations of the term wilful misconduct in private international law conventions refer to M Clarke, *International Carriage of Goods by Road: CMR* (Informa Law from Routledge 2014), paras 100 to 103 and D Mclean et al; *Shawcross and Beaumont on Air Law* (Lexis Nexis 2017), Chapter 30, paras 515 to 534.

income incurred as a result of the damage/destruction of the property and the cost of taking measures following the collision to prevent further damage. Considering the catastrophic potential of collisions with NEOs, a limit on a per claim basis shall be set in the Treaty, especially if the drafters opt for a liberal definition of the term damage. Setting such a limit is important as it will assist the calculation of the contributions to the Fund and will make less likely a scenario where the Fund runs out of money before compensating the victims. At the same time, a provision giving priority to claims for personal injury over property damage shall be included in the eventuality that there are not enough funds to cover both of them.

Distinguishing culpability from recovery is important for an additional reason. It gives the message that "we are all in this together", contributing, as such, in the trust-building exercise and the normalisation of life that slowly takes place after every risk event. Litigation will inevitably slow down this process, as its adversarial characteristics will bring to the public nothing but disappointment and a sense of betrayal, especially if accompanied by delays in receiving the compensation.[81]

It would be impossible to create a liability system that is immune from litigation. Still, the opportunities to litigate in the aftermath of a NEO-risk event shall be limited to the following two occasions: i) the victims shall be given the right to bring an action against the Fund before the courts of the place where the damage took place in case the settlement negotiations fail; and ii) the Fund shall be given the right to recover from States (Parties or not) that acted unilaterally causing or facilitating damage that was covered by the Fund. It is important that the right of recourse against non-conforming States is retained by the Fund so that the victims are compensated without delay following the risk event and are not involved in a process that might require sensitive diplomatic negotiations. These (most probably) protracted and expensive attempts for recovery shall fall on an Institution that has the means to deal with such eventuality.

4.3.3.3 Parallel establishment of domestic funds

Thirdly, it is important that the Treaty permits domestic funds to be set up dealing with compensation. States might set these up if they are willing to give compensation to their residents on top of the limits provided by the Fund. However, the conditions under which these funds will provide compensation shall be aligned to the requirements of the Treaty, i.e. types of recoverable damages. Their only function would be to pay additional compensation to the victims without any rights of recourse shall be left to the Fund to pursue.

5. Conclusion

[81] G Leloudas, *Risk and liability in air law* (Informa 2009), para. 8.9.

In conclusion, NEOs represent a major, yet underestimated, threat to our planet and possibly to our future as species. The current efforts undertaken are inefficient, because they are not globally coordinated and have limited financial resources.

The most appropriate solution would be to create an international organisation that will be in charge of the three risk management phases of NEOs, i.e. financial support for R&D related to identification and mitigation of NEOs (precautionary risk management), decision-making mechanisms to face an imminent NEO threat (proactive risk management) and funding the rescue efforts and compensating victims (reactive risk management). This would be a *sui generis* construction that reflects the unique characteristics of NEOs.

The analysis in this paper is by no means exhaustive. It purports to contribute to the dialogue that (reluctantly) takes place on the future regulation of NEOs by arguing that the effectiveness of our planetary defences requires unique regulatory solutions. In that respect, it is suggested that the drafters of such scheme shall be prepared to break away from traditional methods of international regulation which limit themselves on mitigating the effects of a risk event rather than preventing its occurrence. The catastrophic potential of the risk that we are dealing with leaves no other option.