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PELLA VILYA: NEAR EARTH OBJECTS – PLANETARY DEFENCE THROUGH THE REGULATION OF RESOURCE UTILISATION

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ABSTRACT

Reactions to Near Earth Objects (NEOs) in the past decade have run the gamut from expectations of Armageddon-type scenarios to Eureka moments of revolutionary scientific ideas. Concerns over the potentially devastating effects of an unmitigated collision jostle with forecasts of untold economic returns from the utilisation of NEO resources. Drawing from recent analogies and examples from the field of international environmental law, this paper proposes the development of a legal framework for the regulation of NEO resource utilisation. The proposed legal framework also includes a mechanism to ensure the political will and economic investment necessary for technological advances in planetary defence. By twinning the threats and opportunities presented by NEOs, this paper also analyses the position of theme-specific space law development in the overall legal framework of space exploration and traffic management.

I. INTRODUCTION

Immense fascination has been generated by Near Earth Objects (NEOs) with public, commercial and scientific interest vacillating between the two extremes of Armageddon- and El Dorado-type scenarios. A catastrophic collision between the Earth and an NEO is a clear "low probability, high consequence event"[1] – while there has been no record of fatalities caused by such a collision, it is now undisputed that various NEO collisions in the past has led to mass localised and global destruction.[2] It must be noted that NEO collisions with the Earth is not a thing of the distant past. There have been several instances of large NEOs colliding with the Earth or exploding in the Earth's atmosphere in the last century, with one of the most significant collisions by a 60-meter asteroid in Tunguska, Siberia on 30 June 1908.[3] As of 31 August 2008, 208 NEO impact risks are listed by the website of the Near Earth Object Program of the United States' National Aeronautics and Space Administration (NASA).[4] Of these, only one asteroid 2007 VK_{184} is listed with Torino Scale 0,[5] with the other 207 listed as being equal or smaller than 50 meters in diameter, and therefore of little or no threat to the general public.[6] However, without prompt preventive action, a large NEO is likely to collide with the Earth at some point, with catastrophic consequences.[7]

On the other hand, it has been demonstrated that NEOs are comprised of minerals that are extremely valuable for various applications.[8] With burgeoning costs of Earth-based resource acquisition and rapidly advancing space-oriented technology, NEO resource extraction and utilisation is fast becoming a reality. Aside from supporting space exploration, the large-scale acquisition and utilisation of resources from NEOs for Earth-based activities may soon become economically and technically feasible.

Presently however, there is a lacuna in the international legal framework with regard to NEOs. Aside from a blanket prohibition on appropriation of outer space,[9] including celestial bodies, there is no mention in any legal texts of NEOs. This is a dangerous void, as without a clear and consistent regulatory framework, there cannot be an effective development of technologies, scientific exploration, and economic policies with regard to NEOs. Coupled with the potential hazards of NEOs and the fact that capital investment into both the deflection and utilisation of NEOs will only be viable with a clear regulatory framework, the need for an enunciation of the international legal standards in this field is increasingly pressing.

A possible legal framework is proposed in this paper that twins the economic utilisation of NEO-extracted resources with the scientific research and development necessary for planetary defence against a possible collision. It is mooted that public funding into NEO deflection and planetary defence is unviable for a long-term, sustained effort. On the other hand, NEO resource utilisation for economic

benefit is presently prohibited by law. This paper makes the case for a comprehensive, doubly-dependent regulatory system, which combines the motivation from economic exploitation of NEO-extracted resources with the public good provided by deflection technologies. Economic policy instruments are proposed, based on an analogy from international environmental law, for a harmonised, integrated approach to NEO utilisation and planetary defence. The historical context relating to the international legal framework and the scientific and economic background of NEOs is first discussed.

II. CONTEXT – NEAR EARTH OBJECTS: THE GOOD, THE BAD AND THE UGLY

Issues raised by NEOs typify the classical "the good, the bad and the ugly" debates. The "good" comprise the possibility of economically sound resource extraction and utilisation – providing a potential infinite source of presently-scarce resources for both Earth-based applications and space-based exploration. The "bad" relates to the threat caused by an uncontrolled NEO collision with the Earth, and the catastrophic consequences of impact. The "ugly" fact is that the international legal regime is not ready to deal either with the "good" or the "bad" scenarios. This section looks in more detail at these three contextual issues underlying present and future approaches to NEOs.

1. The Good: NEO Resource Extraction and Utilisation

The Earth's resource base is complex, differentiated, and limited. Resource extraction from the Earth has taken place from the cradle of civilisation.[10] Although supplies of fossil fuels and mineral resources are not likely to be fully depleted for decades, an important junction has been reached in the history of Humanity where the limits of the Earth's resources can be identified.[11] As the most easily-accessible resources are being depleted, lower-grade substances obtained through more costly, damaging and dangerous methods are being used. In the light of these developments, the extraction and utilisation of space-based resources, especially those of near-Earth space, is becoming more viable and attractive.[12]

In particular, NEOs may be the most viable source of valuable minerals and compounds.[13] This is mainly due to two reasons: the mineral composition of NEOs, and their low surface gravity, which decreases the mission energy requirements for orbital manoeuvre.[14] Spectroscopic studies and ground truthing have shown that NEOs comprise stony silicates with semiconductor- and platinum-group metals,[15] bituminous and carbonaceous compounds,[16] ice and clay,[17] non-metals,[18] and large amounts of nickel-iron alloys.[19] Of particular interest are the platinum-group metals, consisting of platinum, palladium, rhodium, ruthenium, iridium and osmium; as well as the occurrence of gold.[20] These metal ores are of especial economic and manufacturing value. Further, some of the volatiles believed to be in NEOs include water ice, carbon monoxide, carbon dioxide, and a conglomerate of carbon, hydrogen, oxygen and nitrogen (CHON), which may be harnessed to produce volatile propellants.[21]

Once engineering-wise possible, NEO mining is expected to transform the economic and technical dynamics of resource production. Robotic NEO mining has been argued to have several advantages over terrestrial mining. These include a higher success rate in prospecting, higher grade ore for processing and less environmental damage to the Earth.[22] This ability to cost-effectively meet existing market demands will allow the minimisation of capital injections as well as the time to return on investment.[23]

2. The Bad: The NEO Threat

NEOs are estimated to impact the Earth approximately twice every million years, causing global ecological disaster.[24] International efforts to create a comprehensive catalogue of NEOs has been undertaken by several governmental, scientific, non-governmental and professional associations, including Spacewatch,[25] NASA's Near Earth Object Program,[26] the Lincoln Laboratory's Near-Earth Asteroid Research,[27] the Japanese Hayabusa mission[28] and the European Space Agency's proposed Don Quijote mission.[29] As a result, the number of known NEOs and their orbits has exponentially increased. Figure 1 below shows the discoveries of Near-Earth Asteroids at half-year intervals in the period 1995 – 2008.[30] At present, more than 400 Near-Earth Asteroids are catalogued.

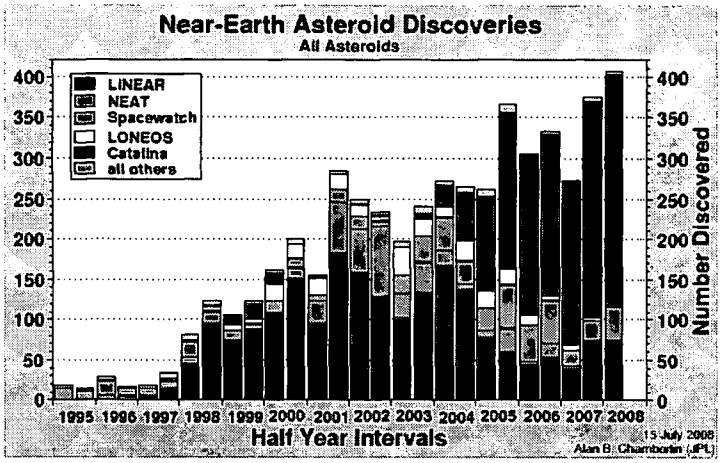

Figure 1: Near-Earth Asteroid Discoveries (1995 – 2008)

Immediate consequences[31] of a major NEO impact include the radiation from the explosion, firestorms, acid rain, pyrotoxin production, volcanism and seismic activity, significant environmental disaster (including tsunamis, the possible loss of the ozone layer and a nuclear winter), and massive fatalities, casualties and property damage.[32]

In the case of a potential major NEO impact scenario, scientific studies have found that a deflection of the NEO resulting in a change in orbit is the best method by which to avoid impact.[33] Deflection would ensure that the NEO does not continue on a trajectory directly for the Earth, but would also avoid splintering the NEO body, thereby creating the scenario that instead of one big NEO impact, the Earth would face a series of smaller NEOs, all of which would in any case have great consequences. It has also been pointed out that a nuclear powered deflection is the only means at present that is of sufficient energy to adequately deflect an approaching NEO.[34] It must be noted however, that the deflection of a threatening object is still in a "conceptual phase".[35] Serious technical issues are still under consideration at the international level.

3. The Ugly: International Space Law is Not Ready

Given the high-risk potential consequences of an NEO impact, as well as the immense economic and scientific benefits of NEO resource extraction, it may come as a surprise that the international legal community has not yet jumped on the bandwagon. There is no legal framework that either ensures the development of technologies to protect the Earth in case of an impact, or enables the effective extraction and utilisation of resources from NEOs. In fact, the present international legal framework may actually hinder both.

Article II of the Outer Space Treaty provides that

> Outer space, including the moon and other celestial bodies, is not subject to national appropriation by claim of sovereignty, by means of use or occupation, or by any other means.[36]

Ostensibly this was to ensure the preservation of outer space and its resources for the benefit of all Mankind as elucidated in Article I. Read together with Article VI of the Outer Space Treaty, which stipulates the obligation of States to bear international responsibility for national activities in outer space, whether such activities are carried on by governmental agencies or non-governmental entities, it is clear that the international legal framework does not allow the commercial exploitation of resources from celestial bodies. In light of the fact that Article VI also requires States to authorise and continually supervise national activities in outer space, this meant that States were under the obligation to ensure, through a licensing system, that commercial entities registered in their territories did not violate Article II.[37] Without being able to "appropriate", by "use or occupation", outer space and its celestial bodies, there is arguably no real motivation either for commercial entities to invest in NEO mining. There is no further provision in any of the international legal texts relating to space activities for the extraction and use of resources from outer space.

With regard to the deflection of NEOs, the international legal regime appears to run counter to convention scientific thought. As discussed above, it has been agreed that a

nuclear-powered deflection would be one of the only feasible methods by which to deflect a threatening NEO. However, given the prohibition on the placement of nuclear weapons in orbit according to Article IV of the Outer Space Treaty, as well as the general prohibition on the use of nuclear weapons as envisaged by the Comprehensive Test Ban Treaty,[38] it seems that the international legal community is set against the use of nuclear weapons in outer space. It can of course be mooted that, in the case of an impending impact, the international legal community will not stand in the way of the use of a nuclear warhead for the non-aggressive deflection of the NEO. However, the prohibition on the placement of nuclear weapons in orbit (as well as on the Moon)[39] can be seen as a *prima facie* opposition to the use of nuclear weapons in outer space.

The foregoing discussion evinces a clear lack of specific legal provision for the equitable and effective commercial mining of NEO resources, as well as an equivocal stance on the use of nuclear weapons in outer space. It is submitted that this status of the law cannot be left as it is. Firstly, with progressive developments in space technology and the crippling prices of Earth-based resources, it is likely that the commercial use of space resources, such as those on NEOs, will become quickly a reality. In this case it would be desirable to have a clear and consistent legal framework in place so as to safeguard the principles of the Outer Space Treaty, while remaining relevant to the ambient developments in the field. Secondly, the legal framework has often served as a possible means of motivation by which to achieve certain aims. In this case, the international legal framework would be a mechanism by which to stimulate research and development into the requisite technology to deflect a threatening NEO. It cannot be overstated that time of is the essence. Given the slowdown in available public funding for such research, and the fact that an NEO collision, while not soon, is in any case likely, it is submitted that commercial and private funding would be the most feasible means of sustaining a long-term perspective into such research. Further, it is submitted that the international legal framework should evolve a mechanism by which to stimulate such commercial and private funding through the use of legal and economic policy instruments.

Before elaborating on the proposed framework, the next section will take a look at recent developments in international environmental law. In that field, legal and economic policy instruments have been employed to quite some success in motivating research and development, as well as behaviour and action, in the furtherance of environmental protection. It is submitted that the example of such legal and economic policy instruments can be adapted to deal with the issue of NEOs in international space law.

III. THE INTERNATIONAL ENVIRONMENTAL LAW ANALOGY

Environmental protection is an overarching goal that has direct implications on a plethora of stakeholders on various levels. States, international organisations, non-governmental organisations, private corporations and individuals all count amongst the potential beneficiaries of positive environmental policy; as well as the potential victims of any environmental disaster. The global reach of the environment, however, has not in itself correspondingly produced global responses in terms of research, development and pro-active initiatives for its protection.

1. Motivation from Economic Policy Instruments

The lack of tangible results in achieving environmentally cleaner technology and products through environmental regulations led in recent years to a re-thinking of motivational instruments. Amongst the carrots suggested is the use of economic policy instruments to protect the environment.[40] With the belief that traditional legal and policy mechanisms have failed to provide adequate incentives to ensure the achievement of environmental objectives, the use of economic instruments is based on the logic that market incentives can guide State, business and organisational behaviour.[41]

A growing number of States have supported the use of economic policy instruments at the international level for global environmental protection.[42] However, the use of economic policy instruments at the international level complementary to legal regulation is a novel development.[43] However, once the idea was mooted at the international level, it quickly found its way into various significant environmental fora, including the 1992 Climate Change Convention,[44] the 1992 Biodiversity Convention,[45] and the 1992 Rio Declaration.[46]

Various forms of economic instruments are recommended for promoting environmental protection, including charges and taxes, marketable permits, deposit-refund systems,

financial assistance, enforcement incentives, administrative charges, liability and compensation for damage, trade measures and consumer information incentives, non-compliance fees and performance bonds, and subsidies. For the purposes of this paper, emphasis will be put on joint implementation and tradable permits, as well as investment incentives, in the framework of integrated pollution control.

2. Joint Implementation and Tradable Permits

The original idea of using tradable permits in the implementation of environmental initiatives was drawn from the 1990 amendment to the United States of America's Clean Air Act.[47] The notion of tradable permits involved granting to certain regions or utilities a number of pollution rights. If these regions or utilities used less than the allocated amount, the excess rights may be sold to another region or utility. The first international framework employing this format was adopted by the European Commission (EC) in 2002, granting parties the right to jointly implement programmes without specifying criteria or specific pollution limits.[48] As such, there was no intention by the EC drafters for inter-State trading in the allocated permits. Tradable permits were first enunciated in Article 2(7) of the 1987 Montreal Protocol,[49] by which member States agreed to "jointly fulfil their obligations respecting consumption" of certain ozone-depleting substances so long as their total consumption level did not exceed the levels stipulated by the Protocol.

A break-through step was taken by the 1992 Climate Change Convention. In that framework Convention, developed member States, together with other Annex 1 parties, were allowed to implement policies required under Article 4(2)(a) and 4(2)(b) "jointly with other parties", subject to decisions made by the conference of parties "regarding criteria for joint implementation".[50] Details with regard to the specific implementation of this framework Convention were answered by the 1997 Kyoto Protocol,[51] which enunciates clear provisions in respect of the joint implementation of the obligations in the Climate Change Convention.[52] A system of tradable permits, called "emission reduction units", emerged from the Kyoto Protocol, as elaborated by the States Parties at their first meeting.[53]

The next positive step was undertaken by the EC Council in March 2003. The Council issued a Directive establishing the scheme for greenhouse gas emission allowance trading, aimed at the reduction of greenhouse gas emissions in a "cost-effective and economically efficient manner".[54] The EC Directive also indicated that such reduction projects be linked with the mechanisms envisaged by the Kyoto Protocol, including joint implementation and the Clean Development Mechanism. The Directive thus established an international trading scheme premised on allocated allowances to certain installation operators for the reduction of greenhouse gases as a result of their activities.[55] Further, harmonised joint implementation of the trading scheme is ensured by the EC Directive's requirement that all member States ensure as of 01 January 2005 that these activities and the trading scheme provide be authorised by a competent authority.[56] What is significant is that each member State is required to adopt a national allocation plan consistent with their obligations under the Kyoto Protocol and EC law, with allowances for the period 01 January 2005 – 01 January 2008 to be allocated free of charge. Moreover, 90% of allocations made for the period 01 January 2008 – 01 January 2013 are also to be allocated free of charge. These allowances will be transferable between persons within the EU and between persons within the EU and third States as listed in Annex B to the Kyoto Protocol. The EC has also adopted guidelines on monitoring and reporting, requiring member States to ensure the due monitoring of emissions and the verification of reports submitted by operators.[57] Each member State is also obliged to establish a registry for the accurate holding, transfer, accounting and cancellation of allowances. These registries are to work in close cooperation with the EC's central independent transaction log to allow for automated checks.[58]

3. Investment Incentives

Mechanisms exploring the use of investment incentives for environmental protection have recently been adopted. In particular, such investment incentives are targeting investment into clean technologies for developing countries and countries with economies in transition. An excellent example of a framework put up for investment incentives is the Clean Development Mechanism established by the Kyoto Protocol. The Clean Development Mechanism ensures the provision of credits to States whose private companies invest in greenhouse gas reduction activities in other States.[59] There has also been a recent trend at the international level to provide financial and technological assistance to developing

countries that invest in clean technologies pursuant to international ozone-related and environmental agreements.[60]

4. Integrated Pollution Control

There is a growing awareness of the cross-cutting nature of pollution and environmental degradation. The traditional method of addressing specific activities or substances belies the fact that each environmental medium has effects on a range of media as they accumulate in the environment. Therefore, dealing with environmental protection on a medium-by-medium basis is certainly not the most efficient or effective method.

In 1991, the Organisation for Economic Co-operation and Development (OECD) Council issued a Recommendation for "integrated pollution prevention (or control)".[61] The harmonised, integrated system is aimed at a more holistic perspective on environmental protection, including a "cradle-to-grave" approach to entire "streams" of environmental degradation.[62] This initiative has led to the adoption of the first international rules on integrated pollution control by the European Union in 1996. The OECD Recommendation acknowledged that certain policies were significant in ensuring an integrated approach, including a change in institutional arrangements, management techniques and technical know-how. Co-ordination mechanisms and cooperative arrangements within different levels of governments amongst various States would be vital to the integrated approach. Such mechanisms would take the form of integrated inspection and enforcement mechanisms, economic policy instruments, life cycle analysis and the more effective monitoring of inventories and registries.

It must be noted that to date, there is no international legal framework that establishes the principles of integrated pollution control in environmental law. Despite the efforts of the International Union for Conservation of Nature's (IUCN) Commission on Environmental Law, it is not likely that such a legal framework will be adopted in the near future. The lack of such a central framework document has resulted in a fragmentary corpus of legal regulations, together with all the well-known problems and drawbacks of a piecemeal development of the law. In this regard, it has been suggested that three issues must be addressed urgently: the establishment of improved mechanisms for the identification of critical priorities for law-making; the guarantee that all stakeholders will be able to effectively participate in the law-making process at the international and transnational level; and the improvement of coordination between international organisations, States, non-governmental organisations and other relevant entities. Any legal rules established must also be accompanied by a range of effective economic policy instruments to motivate compliance. The framework initiated by the 1992 Climate Change Convention, and detailed by the 1997 Kyoto Protocol, as well as subsequent developments thereto, will be significant in the evaluation of the efficacy of economic policy instruments as compliance motivators.

IV. WHERE OPPORTUNITY FITS THE CHALLENGE: PROPOSED FRAMEWORK FOR NEOs

A similar framework of economic policy instruments encased in a legal treaty system is proposed with regard to NEOs. This potentially thorny and complex proposal involves the creation of an international agreement, as a Protocol to the Outer Space Treaty, which allocates tradable NEO mining rights to public or private entities in return for scientific and technical developments in NEO threat deflection. This builds upon the experience gained from embedding economic policy instruments as compliance motivators in the international environmental law framework. By twinning the urgent need for technological advancement in NEO deflection together with the economic incentive of commercial mining, it is submitted that adequate motivation will be provided to ensure private long-term funding of research into NEOs.

1. Proposal: International Legal Framework for NEOs

To adequately address issues relating to NEOs, it is proposed that an international framework treaty be established under the auspices of the United Nations. This proposed United Nations Framework Convention on Near-Earth Objects (FCNEO) should enunciate, in line with the 1967 Outer Space Treaty, the international legal standards applicable to issues relating to NEOs. In compliance with Article VI Outer Space Treaty, the FCNEO should be open to States Parties, which will also represent the interests of their non-governmental and commercial entities. Further, a harmonised integrated approach to NEOs should be coordinated by a United Nations NEO Taskforce, which reports directly to the UN Committee on the Peaceful Uses of Outer

Space (COPUOS).

In essence, the proposed FCNEO will allocate a currency of rights to mine and commercially exploit resources from NEOs in exchange for the publication of certified advancements in NEO threat deflection and planetary defence. These mining and exploitation rights can be allocated to both public and private entities, and are tradable on a newly-created exchange in return for technology transfer, or economic benefits. These rights will function as exceptions to the blanket prohibition on the commercial appropriation and exploitation of natural resources from outer space. The tradability of these rights means that public entities that invest capital into NEO deflection research may also have rights accredited to them, which can be traded with private companies intending to mine NEOs for more research capital injections. Upon the accumulation of a threshold number of these rights to mine NEOs, the entity in question will be allowed to extract and commercially utilise NEO resources, with the caveat that a certain percentage of profits must be put into a UN trust. The framework for this UN trust will be based upon that used for the deep seabed mining regime.[63] Each member State to the FCNEO will be required to establish a registry for the accurate holding, transfer, accounting and cancellation of these rights. These State-maintained registries are to work in close cooperation with the UN's independent registry to allow for automated checks.

The proposed FCNEO structure should have criteria for the joint implementation of initiatives relating to NEOs. A Commission of nominated and highly qualified experts, from the scientific, technical, economic, engineering, legal and policy fields should be set up to provide guidance as to the categories, amount and types of tradable rights to be allocated. This Commission should make annual reports to the COPUOS sessions as to the progressive developments in the field, and should supervise the allocation of such mining rights.

The proposed FCNEO mechanism will broadly work as follows:

a) Negotiation and establishment by the expert Commission of the system of tradable NEO mining rights in exchange for publication of NEO deflection technology, including weighting currency (i.e. what each right credit entails, and what the credit is worth) and exchange mechanisms;
b) Each member State to establish registry of allocated NEO mining rights;
c) Entities with possible technologies for NEO threat deflection to submit these to the expert Commission for verification and weighting;
    i. If the technology is not accepted for credit allocation, the intellectual property remains with the submitting entity. No publication will be made.
    ii. If the technology is accepted for credit allocation, the Commission will indicate the amount of credits to be allocated. If the entity does not agree with the amount, no publication, and no allocation, will be made. In this situation, the intellectual property remains with the submitting entity. If the entity agrees to the allocated credits, the technology must be published in the public domain and the intellectual property over the technology in question is released into the public domain. The Commission allocates the indicated number of mining credits to the entity.
    iii. Entities must register the allocated mining credits with their State.
d) Where there is a dispute or disagreement between the Commission and the entity in question, it should first be settled by negotiation or mediation. If a resolution cannot be brought about by such means, the dispute should be submitted to a three-person arbitral tribunal in accordance with the procedures of the Permanent Court of Arbitration.
e) Entities may trade and transfer the allocated mining credits. Each trade or transfer must be approved by the UN FCNEO Commission.
f) Entities with a threshold number of mining credits, as stipulated by the FCNEO, may undertake mining on NEOs for commercial exploitation of mined resources. A certain X% of profits, as stipulated by the FCNEO, must be deposited in the UN Trust Fund.

2. <u>The Legality of the Proposed Economic Policy Incentive Scheme</u>

Prima facie the legality of the above proposal may be challenged by the argument that it apparently runs counter to the principles as established in the 1967 Outer Space Treaty,

especially that in Article II. However, it is submitted that the proposed framework is legal, for three reasons:

a) Article II Outer Space Treaty must be read and applied in light of the principle of the common benefit of all Mankind.
Article II Outer Space Treaty is to be read subject to Article I, and in light of the Preamble, which stipulates that the exploration and use of outer space is to be for the benefit of all Mankind. Clearly, the progressive development of technology for the successful deflection of threatening NEOs is in the interest of the global community. As such, it is submitted that where the allocation of such mining rights brings benefits for the entire global community, Article II Outer Space Treaty is not violated. Further, the stipulation that a certain percentage of profits from NEO mining should be deposited into a trust similar to that for deep seabed mining also ensures that NEO mining is carried out for the benefit of all Humanity.

b) Progressive developments in the field of international space law must learn, through necessity, from analogous developments in other fields of international law.
Events in international environmental law have shown that economic policy instruments, when embedded into an international legal framework, may provide the necessary impetus and motivation to achieve goals that are beneficial to the global community. In the case of international environmental law, economic policy instruments in the form of tradable emission credits and investment incentives have kickstarted the momentum in favour of environmental protection and action against climate change. It is submitted that the experience from international environmental law may be commuted to space activities, and that the economic policy instruments through tradable credits for NEO mining will also attract private investment into research and development for technologies that can deflect threatening NEOs. Given that the technology to effectively mine NEOs is not so far from technology to deflect NEOs, it is submitted that this economic policy instrument will ensure continued and sustained funding from the private sector. Due to the impossibility of long term public financing for research into NEO deflection, this is a necessary step.

c) The potentially infinite amounts of resources available in outer space will offset the amounts allocated in the proposed framework; furthermore, the technologies gained for the deflection of threatening NEOs outweigh the one-off allocation of mining rights.
Many highly qualified technicians and scientists have argued that the amount of resources available in outer space is potentially infinite.[64] As such, it is submitted that the good gained from allocating mining credits, in the form of publicly available and published technologies for the deflection of threatening NEOs and planetary defence, vastly outweighs the risks inherent in this proposed framework.

3. Perspectives: Steps towards Establishing a Workable Framework

This proposed framework is admittedly rather bold, and flies in the face of conventional thinking in international space law. However, it is submitted that this proposed framework is workable, and indeed contributes to ensuring the relevance of international space law through progressive development in step with the needs and evolution in the field. To establish this framework, the following steps are further proposed:

a) The issue of NEO mining, and the deflection of threatening NEOs, should be undertaken seriously both at the international level (within the UN COPUOS), as well as amongst the experts in the field, for example, within the Committee on Space Research (COSPAR).
b) A Working Group comprising of technical and legal experts should be established to negotiate and draft the proposed Framework Convention, including detailed specifications on the type of deflection technology acceptable for credit allocation, the type and weight of mining credits to be allocated, the trading system, the dispute settlement mechanism, the rights and obligations bestowed by the allocation of such credits, and the functioning of the proposed UN Trust Fund. A Draft Framework Convention should be produced by the Working Group at the end of no more than three years from its

establishment.

c) The Draft Framework Convention should be passed through the UN COPUOS, and then through the UN General Assembly, before being finalised. The finalised Framework Convention should then be opened for signature by interested States. It is important to note that States that are not members of the Convention must abide by the customary international law that outer space, including celestial bodies, cannot be appropriated. Therefore, only the exception as stipulated in this Convention allows commercial mining and resource exploitation of NEOs. This should provide the necessary incentive for States to engage in the proposed framework.

V. CONCLUSION: THEME-SPECIFIC SPACE LAW DEVELOPMENT

It is a rare coincidence that one issue should provide both the problem and the potential solution – and especially so when the solution comes with an incentive that costs nothing and is potentially infinite. Thus, it is the proposal of this paper that the international legal community should seize the opportunity presented by NEOs and enunciated a legal framework that is both creative and necessary. Planetary defence through the regulation of NEO resource utilisation is an elegant solution that should be considered by the international legal community.

The juxtaposition of the threats and opportunities presented by the NEO issue brings to light an interesting point in theme-specific space law development. Just like the horizontal, cross-cutting impact of environmental degradation and protection, it is submitted that such theme-specific space law development adds considerable substance to the overall space traffic management framework. In the case of NEOs, a comprehensive regulatory framework that not only deals with the hazards posed, but also addresses the contemporary issues raised by commercialisation, ensures a thorough handling of all pressing issues related to NEOs. It is submitted that such detailed, compartmentalised handling of a specific theme is a good method by which to ensure that the final, comprehensive legal framework for space traffic management deals with these issues in depth.

Ultimately, such creative legal development methods ensure that when dealing with activities beyond the Earth's airspace, the law can also reach above and beyond the stifling atmosphere of mundane tradition and become truly *pella vilya* – "*beyond air*".[65]

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[1] Gerrard, M.B. and Barber, A.W., "Asteroids and Comets: U.S. and International Law and the Lowest-Probability, Highest Consequence Risk", (1997) 6 New York University Environmental Law Journal 4.

[2] The impact of a 10-kilometer-wide NEO at Chicxulub, Mexico, for example, left a 180-kilometer diameter crater. It has been argued that the impact of this NEO was one of the factors that caused the mass extinction at the end of the Cretaceous Period (approximately 65 million years ago). See Bottke, W.F., Vokrouhlicky, D. and Nesvorny, D., "An asteroid breakup 160 Myr ago as the probable source of the K/T impactor", (September 2007) 449 Nature 23; for an opposing view see Keller, G. et al, "Chicxulub impact predates K-T boundary: New evidence from Brazos, Texas", (2007) 255 Earth and Planetary Science Letters 1.

[3] Other significant collisions include the airborne explosion at Curuca River, Brazil (1930), at Sikhote-Alin, Siberia (1947), over Revelstoke, Canada (1965), over Ontario, Canada (1966), over Alaska, United States of America (1969) and in Honduras (1996). The 1908 Tunguska event incinerated hundreds of acres of forest in Siberia, and had it impacted on a populated area (over St. Petersburg, for example, had it been approximately four hours later), would have caused catastrophic fatalities and damage. The 100 million kilogramme asteroid entered the Earth's atmosphere at about 54,000 kilometres per hour, and exploded at a height of approximately 8.5 kilometres above the ground. The explosion released energy equivalent to 185 times that released by the atomic bomb at Hiroshima. A century on in 2008, the requisite technology required to deflect an NEO such as the Tunguska asteroid is still lacking. See Space Daily, "Tunguska Event Still a Mystery 100 Years On", (30 June 2008), online at http://www.spacedaily.com/reports/Tunguska_Event_Still_A_Mystery_100_Years_OnTunguska_Event_Still_A_Mystery_100_Years_On_999.html/, accessed 31 August 2008.

[4] Online at http://neo.jpl.nasa.gov/, accessed 31 August 2008.

[5] The Torino Scale provides an assessment of asteroid and comet impact hazard predictions based on a 0 – 10 point scale. See Morrison D. et al, "Impacts and the Public: Communicating the Nature of the Impact Hazard" in Belton, M.J.S. et al (eds.), *Mitigation of Hazardous Comets and Asteroids*, (2004). NASA's Near Earth Object Program provides a graphical illustration of the Torino Scale online at http://neo.jpl.nasa.gov/images/torino_scale.jpg, accessed 31 August 2008.

[6] NASA Near Earth Object Program, "Sentry Risk Table", online at http://neo.jpl.nasa.gov/risk/, accessed 31 August 2008.
[7] Tate, J.R., "Near Earth Objects – a threat and an opportunity", (2003) 38(3) Physics Education 218.
[8] See on the topic of the utilisation of NEO and near space resources, Wingo, D., *Moonrush: Improving Life on Earth with the Moon's Resource*, (2004); Binzel, R.P. et al, "Physical Properties of Near-Earth Objects", in Bottke, W.F. et al (eds.), *Asteroids III* (2002) 264; Sonter, M.J., "Near Earth Objects as Resources for Space Industrialization", (2001) 1(1) Solar System Development Journal 1; Lewis, J.S., Matthews, M.S. and Guerrieri, M., "Resources of Near-Earth Space", (1993); Hartmann, W.K., "The Resource Base in Our Solar System", in Finney, B.R. and Jones, E.M., *Interstellar Migration and the Human Experience*, (1985) 26.
[9] Article II, Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space Including the Moon and Other Celestial Bodies, (1967) 610 UNTS 205, hereinafter "Outer Space Treaty". As of 01 January 2008, 98 States have ratified the Treaty, and an additional 27 States have signed it.
[10] See for example Lynch, M., *Mining in World History (Globalities)*, (2004) at p. 3.
[11] See on the topic, Guthery, F.S., *A Primer on Natural Resource Science*, (2008); Pirages D. and Cousins K., *From Resource Scarcity to Ecological Security: Exploring New Limits to Growth*, (2005); Rogers, J.J.W. and Feiss, P.G., *People and the Earth: Basic Issues in the Sustainability of Resources and Environment* (1998); and Constanza R. et al, *A New Century for Natural Resources Management* (1995).
[12] See generally Schrunk D. et al, *The Moon: Resources, Future Development and Settlement* (2007); and Lewis, J.S., *Mining the Sky: Untold Riches from the Asteroids, Comets and Planets* (1997).
[13] An excellent overview of contemporary issues relating to NEOs can be found in Milani, A., Valsecchi, G.B. and Vokrouhlicky, D., *Near Earth Objects, our Celestial Neighbours (IAU S236): Opportunity and Risk (Proceedings of the International Astronomical Union Symposia and Colloquia)*, (2007).
[14] This means, in practical terms that less scalar effort is required to carry the payload from one orbit into another – that it would be easier to lift the load off the surface of the NEO, and also easier to transfer it into Earth orbit.
[15] Kuck, D.L., "Near-Earth Extraterrestrial Resources", (1979) Space Manufacturing Facilities 3. See also Gertsch R., Gertsch L. and Remo J.L, (eds.), "Mining near-Earth resources in near-Earth objects, the United Nations International Conference", (1997) 822 Annals of the New York Academy of Science 468.
[16] Zuppero, A.C., "Discovery of Abundant Accessible Hydrocarbons Nearly Everywhere in the Solar System", (1996) Proceedings of the 5th International Conference on Engineering, Construction, and Operations in Space, American Society of Civil Engineers 96.
[17] Lewis, J.S., "Resources of the Asteroids", (1997) 50 Journal of the British Interplanetary Society 51.
[18] These include olivine, pyroxene, plagioclase feldspar, arsenic, selenium, germanium, phosphorous, carbon and sulphur. See O'Leary, B. et al, *Retrieval of Asteroidal Materials, Space Resources and Settlements*, (1979) NASA SP-428 pp. 142 – 155.
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[20] Horan, M.F., Walker, R.J. and Morgan, J.W., "High Precision Measurements of Pt and Os in Chrondrites", (2001) Lunar and Planetary Science XXX.
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[22] See Sonter, M.J., "Near Earth Objects as Resources for Space Industrialization", see *supra* note 8.
[23] Gerlach, C.L., "Profitably Exploiting Near-Earth Object Resources", paper given at the International Space Development Conference, National Space Society, Washington DC, 19 – 22 May 2005 at p. 11.
[24] Morrison, D. et al, "Dealing with the Impact Hazard", in Bottke W.F. et al (eds.), *Asteroids III*, (2002) pp. 739 ff.
[25] The Spacewatch Project, Lunar and Planetary Laboratory, University of Arizona, website at http://spacewatch.lpl.arizona.edu/, accessed 31 August 2008.
[26] Near Earth Object Program, NASA, see *supra* note 4.
[27] Lincoln Laboratory, Near-Earth Asteroid Research (LINEAR), Massachusetts Institute of Technology, website at http://www.ll.mit.edu/mission/space/linear/, accessed 31 August 2008.
[28] Hayabusa mission, Japan Aerospace Exploration Agency, website at http://www.muses-c.isas.ac.jp/e/index.html, accessed 31 August 2008.
[29] European Space Agency, NEO Space Mission Preparation, Don Quijote mission, information online at http://www.esa.int/SPECIALS/NEO/SEMZRZNVGJE_0.html, accessed 31 August 2008.
[30] Figure 1 is from Chamberlin, A.B., Jet Propulsion Laboratory, online at http://neo.jpl.nasa.gov/stats/, accessed 31 August 2008.
[31] Chapman, C.R., Harris, A.W. and Binzel, R., "Physical properties of near-Earth asteroids: implications for the hazard issue", in Gehrels, T., (ed.) *Hazards Due to Asteroids and Comets* (1994) 537.
[32] See *supra* note 7 at p. 218.
[33] NASA, *Near-Earth Object Survey and Deflection Analysis of Alternatives*, Report to Congress, (March 2007), online at http://www.nasa.gov/pdf/171331main_NEO_report_march07.pdf, accessed 31 August 2008.
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[35] George Washington University, *Summary and Recommendations from the 2007 Planetary Defense Conference*, 05 – 08 March 2007, (25 April 2007), at p. 3.
[36] See *supra* note 9.
[37] See on the topic of non-appropriation and Article II of the Outer Space Treaty generally Li, S., "Thoughts on relation between individual and the principle of inappropriation of outer space", in Papers Collection: International Forum on Air and Space Law (2007) 390 (in Chinese); von der Dunk, F.G., Back-Impallomeni, E., Hobe, S. and Ramirez de Arellano,

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[38] Comprehensive Nuclear Test Ban Treaty, (1996) 35 ILM 1439.

[39] Article 3(3), Agreement Governing the Activities of States on the Moon and Other Celestial Bodies, (1979) 18 ILM 1434, hereinafter "Moon Agreement". As of 01 January 2008, 13 States have ratified the Agreement, and 4 States have signed it.

[40] Sands, P., *Principles of International Environmental Law*, (2nd ed., 2003) at p. 158 ff.

[41] For an excellent overview of the use of economic instruments in international environmental protection, see generally Stewart, R., "The Importance of Law and Economics for European Environmental Law", (2002) 2 Yearbook of European Environmental Law 856; Bosselmann K. and Richardson B., *Environmental Justice and Market Mechanisms* (1999) and Galizzi, P., "Economic Instruments as Tools for the Protection of the International Environment", (1997) 6 European Environmental Law Review 155.

[42] One of the earliest initiatives can be found in "Report of the Working Group of Experts from the EC Member States on the Use of Economic and Fiscal Instruments in EC Environmental Policy", (1991) 14 BCICLR 447.

[43] It was only in April 1990, for example, that the European Commission (EC) Environmental Council "acknowledged the value of supplementing existing regulatory instruments...by the use of economic and fiscal instruments", see "Report of the Working Group of Experts from EC Member States on the use of Economic and Fiscal Instruments in EC Environmental Policy", *ibidem* at p. 448. The first global declaration in support of economic instruments in this regard was in November 1990, with the Ministerial Declaration of the Second World Climate Conference.

[44] Developed States Parties to the Convention are obliged to coordinate their relevant economic instruments in regard of climate change issues, see Article 4(2)(e), United Nations Framework Convention on Climate Change, (1992) 31 ILM 851, hereinafter "Climate Change Convention".

[45] States Parties are called upon to adopt economically and socially sound measures that act as incentives for the conservation and sustainable use of components of biological diversity in Article 11, Convention on Biological Diversity, (1991) 31 ILM 818.

[46] Rio Declaration on Environment and Development (1992) 31 ILM 874, hereinafter "Rio Declaration".

[47] USC §§ 7401 – 7671 (1988), and amendments there to in Supplement III to USC (1991). See for an overview on the topic Nash, J. and Revesz, R., "Markets and Geography: Designing Marketable Permit Schemes to Control Local and Regional Pollutants", (2001) 28 Ecology Law Quarterly 569.

[48] Article 4(2), Convention for the Prevention of Marine Pollution from Land-Based Sources (Paris), (1974) 13 ILM 352, as amended by the Protocol of 1986, (1988) 27 ILM 625.

[49] Protocol on Substances that Deplete the Ozone Layer (Montreal), (1987) 26 ILM 1550.

[50] An excellent discussion of the topic can be found in Sands, P., *Principles of International Environmental Law*, *supra* note 40 at pp. 357 – 368.

[51] Article 208, Protocol to the Framework Convention on Climate Change (Kyoto), (1997) 36 ILM 1436, hereinafter "Kyoto Protocol".

[52] Gosseries, A., "The Legal Architecture of Joint Implementation", (1999) 7 New York University Environmental Law Journal 49.

[53] Stewart, R.B., Connaughton, J.L. and Foxhall L.C., "Designing an International Greenhouse Gas Emissions Trading System", (2001) 15 Natural Resources and Environment 160.

[54] See Articles 1 and 26(3) of the European Council Directive, online at http://europa.eu.int/comm/environment/climat/030318commonposition_en.pdf, accessed 31 August 2008.

[55] Article 2, European Council Directive, *ibidem*. The target operations are energy, production and processing of ferrous metals, the mineral industry and other activities such as the production of pulp and paper (Annex I). Gases targeted are carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons and sulphur hexafluoride (Annex II).

[56] Articles 4 – 7, European Council Directive, *supra* note 54.

[57] Articles 14 and 15; and Annexes IV and V of the European Council Directive, *supra* note 54.

[58] Articles 19 and 20, European Council Directive, *supra* note 54.

[59] See for an overview Sands, P., *Principles of International Environmental Law, supra* note 40 at p. 373 ff.

[60] See for an overview Sands, P., *Principles of International Environmental Law, supra* note 40 at p. 1021 ff.

[61] OECD Council Recommendation on Integrated Pollution Prevention and Control, (1991) C(90)164/FINAL, paragraph I(a).

[62] See for example the draft Directive on Integrated Pollution Prevention and Control: COM (93) 423, (14 September 1993).

[63] On the topic of the legal regime for deep seabed mining, see Mwenda, K., "Deep Sea-bed Mining under Customary International Law", (2000) 7(2) Murdoch University Electronic Journal of Law, online at http://www.murdoch.edu.au/elaw/issues/v7n2/mwenda72.html, accessed 31 August 2008; also see generally Hauser, W., *The Legal Regime for Deep Seabed Mining under the Law of the Sea Convention*, (1983) and Schmidt, M.G. and Richardson, E.L., *Common Heritage or Common Burden? The United States Position on the Development of a Regime for Deep Sea-bed Mining in the Law of the Sea Convention*, (1990).

[64] See *supra* note 15.

[65] Tolkien, J.R.R., *The Lord of the Rings: The Two Towers*, (1966).