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humans, by environmental pollution, since for ensuring ecological stability, species diversity is essential and the pollution of air, water and soil is the major threat for the next generation. To achieve this goal, in every use of space NPS, launching state should take into consideration all precautionary measures required for the protection of natural habitats of the Earth's environment (Farrar, 1972).

b. Pre-assessment, before starting a new activity or project;

c. Developing and producing products and services with no undue environmental impact, which means that they are efficient in their consumption of energy and natural resources as well as having the capability of being recycled, reused, or safely disposed;

d. To develop, design and operate facilities in a way that minimizes adverse environmental impacts and waste generation, and the consideration of responsible wastes disposal;

e. To conduct or support research on the environmental impacts of every technology for using the associated raw materials, products, processes, emissions and wastes of NPS for space activities to minimize such adverse impacts;

f. Precautionary approach which means modifying the manufacture, use of products or services or the conduct of activities consistent with scientific and technical understanding, to prevent serious or irreversible environmental degradation;

g. To devolve and maintain, where significant hazards exist, emergency preparedness plans in conjunction with emergency services, relevant authorities and local community, specially preventing every potential trans-boundary impacts;

h. To transfer environmental friendly technology;

i. Contributing to the common efforts by developing public policy for governmental or non-governmental programs to enhance environmental awareness and protection;

j. Openness to concerns by having dialogue with employees and public, through anticipating and responding to their concerns about the potential hazards of space NPS missions and impacts of operations, products, wastes including those of trans-boundary or global significance;

k. Compliance and reporting by conducting regular environmental audits, and assessment of compliance with aforementioned legal requirements to provide necessary information for the protection of public and the Earth's environment.

In cases that there is a lack of scientific certainty

in relation to an activity like a space NPS mission that may have harmful, damaging, irreversible or trans-generational effects, one of the following three results should be followed:

1. That activity should not be permitted;

2. The benefit from such activity should be weighed compared with the potential environmental damage, considering the likelihood and magnitude of the damage;

3. Appropriate steps should be taken to mitigate the anticipated environmental harm (Kin Dall, 1991).

5- Conclusion

Nowadays, space NPS missions are inevitable. However, they should be safe and reliable in long term. This can be achieved by observing the duties of states specially their liability for damages which may potentially occur and by mitigation of trans-generational and trans-boundary Environmental pollution. It seems that other International Space Law rules which are binding on state parties, who administer, authorize or control space NPS missions, must make sure that safety issues being added and international standards for the development and test of space reactor systems being observed properly. Furthermore the relevant environmental principles as well as the space and nuclear treaty rules should be observed. In that case, public confidence about this kind of space activities will increase and the stability and continuation of these missions will be guaranteed. STSC of COPUOS should develop international technically-based principles which consider goals and recommendations to provide guidance relating to the safety aspects of launch and operation of space NPS missions. It must have some recommendations about design, launch, operation and other relevant phases. Thereafter, national standards and programs should be adapted as a high-level guidance to promote harmonization in these issues, so that some generalized consensus and common understanding regarding the safety of space NPS missions with respect to environmental concerns can be formed.

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liability regime. The lack of clear distinction between physical damage to property and contamination makes the legal principles especially uncertain, and legal principles are used mainly as a means for providing redress for broken bones, and property faces conceptual differences when dealing with imperceptible radioactive emissions and effects (Lee, 2000).

In the case of theft, robbery or any other unlawful taking of nuclear material, state parties shall, in accordance with their national law, provide co-operation and assistance, to the maximum feasible extent, in the recovery and protection of such material to any state that so requests; especially, for informing other parties, exchanging information with each other or with IAEA to co-ordinate through diplomatic and other agreed channels, rendering assistance if requested and ensuring the return of stolen or missing NPS (Articles 1-5).

4-International Environmental Law treaties and space NPS missions

The first international environmental conventions during 1920s-1950s were concerned about plants protection and disease control. The first animal preservation convention was about protecting useful birds for agriculture. The next conventions focused on the protection of endangered seals and whales (1911-1946). The treaty of radioactive testing prevention in the space (1964), the Stockholm conference on man and environment (1972), the convention of Baltic and Mediterranean Seas (1970s), the establishment of UNEP, the London dumping convention for the limitation of hazardous wastes in the seas (1972), the air pollution treaty for the prevention of the acidic rain (1979), Vienna convention for the protection of the ozone layer (1985), Montreal protocol for limiting the use of CFCs for the protection of the ozone layer (1987) (Mossalanejad, 2009) and the 1992 Rio declaration for achieving sustainable development are among the most important treaties codified after World War II. For a sustainable development, both economic and ecological sustainability must be considered. The Brandt land report (1987) has defined sustainable development as the developmental technology which meets the requirements of the present, without preventing the future generations from meeting their own demands.

There is no consensus which general principle of international environmental Law apply on the use

of NPS in space, but there is no doubt about their potential applicability to the terrestrial segments of working with nuclear or radioactive materials, especially in handling, storage, and shipment of these materials. It seems that there may be a supervening notion of international law that imposes duties with respect to the commons (common heritage of mankind) including space, because general customary international law requires all states to behave in a way that do not cause harm to the environment of areas beyond the jurisdiction of any state, including a fortiori, the high seas, space, and the Antarctic (Pinto, 2004). It is called the duty of a state to protect areas which are outside its own jurisdiction, from environmental damage. This notion was established in Trail smelter arbitration (1938) (Trail smelter arbitration (US V. Canada, 1938)). As many environmental notions should clearly be observed in terrestrial activities involving NPS, like the nuclear treaties mentioned earlier, those notions should be considered in space NPS missions.

Some of the most important environmental notions have been introduced by the Stockholm declaration (1972) (UN, GA, Report of UN on the human environment, 1973) but the main problem is that these notions are not legally binding. However, as they have been repeated subsequently in the 1992 Rio declaration (UN, GA, Report on the UN Conference on environment and development, 1992), they seem to be converted to international customary law and must be observed as much as possible (Etemire, 2016). The most relevant principles of these two declarations, due to the use of space NPS and achieving sustainable development, include: “inter-generational equity, use and conservation of natural resources, environmental protection, the precautionary principle, the polluter pays principle, obligation to assist and cooperate, eradication of poverty, and financial assistance to the developing countries (Khitoliya, 2009).

Those principles may help, to some extent, in striking a balance between deployment of space NPS, and the protection and preservation of environment; because every development activity has some impact on the environment, which must be harmonized in such a way that the environment is polluted as little as possible. Measures of achieving sustainable development related to space NPS mission are:

a. Biosphere conservation and pollution control, which means avoiding to endanger the lives of thousands of plants and animals species and even

radical in its approach, perhaps understandably building on and consolidating the existing modern developments in civil liability treaties (Boyle, 2005).

3-Nuclear Treaties and space NPS missions

Recently, legal subcommittee (LSC) of COPUOS lists NPS on its agenda, and declared clearly that it will not working on this item pending STSC consideration of technical issues. So LSC would have a role in working on any type of the required NPS safety framework required. For the time being, focus is placed on the four conventions which are about terrestrial nuclear power applications (UN Doc A/AC.105/781, 2002). It seems that those conventions can be applied in case of an accident involving an NPS re-entering the Earth (Space treaty Doc No. 100-4, Hein's No KAV 2219, 1986). This paper will consider that states duties according to these treaty rules with respect to space NPS missions in following sections.

3-1-The convention on early notification of a nuclear accident

This convention clearly states that all the countries that utilize NPS must take comprehensive measures to ensure a high level of safety in nuclear activities aimed at preventing nuclear accidents and minimizing the consequences thereof. This aim will be achieved by international cooperation in the safe development and use of nuclear energy. State parties therefore should provide relevant information about nuclear accidents as early as possible, which can be carried out by concluding bilateral and multilateral arrangements for the exchange of information. According to Article 2 and 5, those states which are or may be physically affected by the nuclear accident should be notified directly or through the IAEA, about its nature, the time of occurrence, its exact location where appropriate, and the facility or activity involved. Thereafter, the state party providing the information must respond as far as reasonably practicable to request for Further information or consultations sought by an affected state party (Article 6). The state parties may consider conclusion of bilateral or multilateral arrangements relating to the subject matter of this convention.

3-2-The convention on assistance in the case of a nuclear accident or radiological emergency

This convention requires parties to cooperate with each other and with IAEA to minimize consequences of any nuclear accident through concluding

bilateral or multilateral arrangements to facilitate prompt assistance and protect life, property and the environment from the sustainable effects of radiological releases (OST article 1).

3-3-The convention on nuclear safety (1994)

This convention does not apply to space NPS mission, and contains no provision for reporting on or reviewing safety measures to be taken, in relation to such sources. Nevertheless, the safety objectives for radioactive wastes and, where relevant, the specific safety obligations of parties include: "the establishment of a legislative and regulatory framework, which should define the discrete responsibilities of the government, the regulatory body and the operators; to take necessary measures for education and training of the workforce and for the safety of the nuclear facilities to secure the safe operation, safe management and disposal of radioactive waste" (Articles 1-3,33).

General safety considerations are about the obligation of contracting parties to "establish safety policies; undertaking adequate financial resources and sufficient numbers of qualified staff with appropriate education, training and retraining to support the safety of each installation and ensure that capacities and limitations of human performance are taken into account" (Article 27).

3-4-The convention on the physical protection of nuclear material (1979)

Relevance of this convention to space NPS missions relates to protecting or safeguarding nuclear material in international transport prior to launch or subsequent re-entry, which are not directly related to launch nuclear safety. In this respect, every country using NPS shall apply, within the framework of its national law, the levels of physical protection in transportation of nuclear material from a part of that state to another part, through international water or air. Such responsibility for obtaining assurances can be taken by concluding mutual agreement and with respect to sovereignty and jurisdiction of states over their air and territorial sea (Tias No 11080, 1980). The current regimes for civil liability of the nuclear industry were established when the overriding benefits of the peaceful use of nuclear energy seemed to be clear. They pose major difficulties for potential plaintiffs, and significant obstacles remain to be overcome if a wide range of environmental, property and personal interests are to be addressed by a civil

1988). These imprecise provisions of OST were completed by the liability convention which provides a system under which states would be responsible for the space objects to be traced, and the compensation of the damages. According to article I of this convention damage include “loss of life, personal injury or other impairment of health; or loss of or damage to property of states or of persons natural or juridical, or property of international intergovernmental organizations. About the term “space object”, this convention states that this term includes its component parts and its launch vehicles and parts thereof (like space debris). “Launching state” is defined as a state which launches or procures a space object, or from whose territory or facility a space object is launched. It states that launching includes attempted launching. The most important points of this convention which can be invoked for mitigation of the potential risks of NPS missions are:

a. A launching state according to Article II has absolute liability to compensate the damage caused by its space NPS object on the surface of the Earth or by its aircraft, which means liability without proof of fault, if that danger eventuates (the doctrine of dangerous things which is found in relation to damage from aircraft) (Rome Convention, 1952) or in case of nuclear incidents (Paris Convention 1960 on third party liability in the field of Nuclear energy). Where damage is caused elsewhere than on the surface of the Earth by a space NPS object to the space object of another launching state or to persons or property onboard, the liability of launching state according to article III depends upon proof of fault of persons for whom it is responsible (Baker, 1988). It is similar to the operation of the international oil pollution compensation (<http://www.iopcfund.org>).

b. Article IV is about compensation funds for the damage caused by the collision of two space objects elsewhere than on the surface of Earth to a third state or its natural or juridical persons. It specifies that the first two states are jointly and severally liable to the third party and the liability of the launching states is absolute. Where the damage to third state occurs elsewhere, the liability of the first two states is based on proof of their fault or persons for whom either of them is responsible. The damaged state may seek the entire compensation from all or any of the liable launching states. The burden of compensation of liable states is apportioned between them in proportion of their fault.

c. In case of joint launch of a space NPS object, article

V provides that the states are jointly and severally liable for the damage, including passive participants like a state from whose territory or facility a space NPS object is launched. Damaged state may seek entire compensation from all or any of these states having liability.

d. Article VI is about possible exoneration of a launching state from absolute liability, which is granted to the extent that a launching state can establish that the damage has resulted (aggravated negligently or deliberately) wholly or partially by gross negligence of or from an act or omission with intent to cause damage on the part of a claimant state or its natural or juridical persons. It then specifies that this convention does not apply to damaged nationals of launching state or to foreign nationals taking part in the launch of an NPS object or any stage after that, until its descent or while they are in the immediate vicinity of a planned launch or recovery area, if they have been invited for this purpose (Rude sill, 2007).

e. A claim for compensation according to Article VIII may be presented to a launching state by sending an appropriate diplomatic note. If there is no diplomatic relations, that claim can be submitted through a third state or the UN Secretary General, provided both of them are UN members. Another point is that if the state of nationality did not present a claim, then the state where the damage occurred and the state of permanent residence of the damaged person or entity that is not a national of the launching state nor was engaged in operating the space NPS object might respectively claim compensation from the liable state. It means that this convention does not allow any state to set up an international agency or broker for space claims. The last point is that presentation of compensation claim does not require prior exhaustion of local remedies.

The International Law Commission's articles on State Responsibility can provide a legal ground for invoking states duties with respect to their space NPS missions. The Commission recently, embarked on developing a set of specific principles. For the reasons of political pragmatism rather than legal principles, the latest draft proposals of the ILC published last year, have rejected strict liability in favor of loss allocation amongst different actors. The core principles of the proposals are critically assessed against the background of other international and regional initiatives concerning environmental liability. The ILC has been cautious rather than

provided it accepted the rights and obligations of ARRA and the majority of its member states are parties to ARRA and to the OST (Article. VI).

3. Make an appropriate public announcement (Article. I).

4. Notify the UN Secretary General who should disseminate this information promptly (Article I (b)). These duties apply where the incident occurs in the territory under states jurisdiction, on the high seas or somewhere not under the jurisdiction of any state, such as Antarctica (Article IV).

5. The assistance of launching authority in recovery operation is dependent upon the discretion of territorial state and the request for intervention, by providing identifying data (Article V (2) (3)).

6. The expenses of recovery and return are to be borne by launching authority (Article V (5)).

7. In case the object or its component parts contain hazardous or deleterious elements (Article V (4)) as NPS objects, the party finding it may notify the launching authority which has the duty to take effective steps under the direction and control of the contracting party, to eliminate possible danger or harm (Jarvis, 1986).

The important point that this paper is about to raise is that in the case of removal of some NPS objects in the future, these operations should be carried out at the expense of their launching authority. It is to be noted that in this retrieval and return operation, both private and state actors may be involved. Thus, appropriate contracts must be concluded between private sector and states which are responsible for proper registration and control of this kind of space activities. So that expenses of these operations can be covered by the owner/ insurer (Deidrick, 1999).

2-2-3-Liability

Every space object launched to space will re-enter the atmosphere of the Earth due to gravity at some point in the future which may cause damage in coming to rest in the place to be found. Therefore the main duties of launching authority are about their liability to compensate victims and alleviate the environmental damages as much as possible. Principles concerning liability for environmental damage are surprisingly underdeveloped in international law.

In this respect, beside OST, there exists the 1972 liability convention for finding the state of registry that has the liability to compensate for the damages caused by NPS objects. Since the OST and the liability convention are only binding for their parties,

it is important to notice that there is a quadruple regime for the liability with respect to every space activities, which is: “that of OST for its parties, that of the liability convention for its parties, the one under normal international Law (Brownlie, 1990) and finally there might be recourse to a remedy under a national law.

Liability under the OST includes the following points which can be invoked for mitigation of the potential risks of NPS missions:

a. Articles I (2) and III of OST indicate that the space must be used in accordance with the international Law. Thus, it can be deduced that the ordinary rule of international law as to compensation for the damage caused by one state to another state applies in space-related incidents.

b. Article VII of OST provides that parties who launch or procure the launch of an object into the space, or from whose territory or facilities a launch takes place, are internationally liable for the damage done to another state party or to its natural or Juridical persons on the Earth, in air or in the space.

c. Article VI of OST states that parties to the treaty bear international responsibility for national activities in space, whether such activities are carried out by governmental or non-governmental entities, and for ensuring that national activities are carried out in accordance with the provisions of the treaty. Further, the activities of non-governmental entities in space shall require authorization and continuing supervision by the appropriate state party to the treaty. If, therefore, the activities of nationals cause damage, a nexus is constituted between them and it is sufficient that home state impute liability on the part of state.

d. The OST Article VIII is about the concept of registry of space objects which should be maintained by individual states. Because, this article provides that a state on whose registry an object launched into space is carried, retains jurisdiction and control over the object and over any personnel onboard while it is in the space or on a celestial body (Jasentuliyana, 1999). Simply this means that a state cannot get out of its international obligations through the abandonment of space NPS object.

This paper aim is to call upon state duties according to the provisions of OST which provide a fix responsibility to authorize and supervise space activities. This closes the door to the avoidance of liability, since state parties have the duties as to continuous control and supervision (Hennessey,

to following reasons in case of any damage, the liability of states can be invoked: (1) a state does not lose jurisdiction over an object by launching it into space; and (2) objects in space remain subject to the supervision of the launching state that registered it.

2-2-Other space treaties

Other three UN space treaties which are relevant and had been considered by this paper for mitigation of the potential risks of NPS missions are the Agreement on the Rescue and Return of Astronauts (ARRA) of 1968, the liability convention of 1972 and the Registration convention of 1975. As they expand the provisions of OST, giving their parties a degree of precision to the rights and duties of states in the exploitation and use of space, which is extremely helpful in space NPS missions, due to the fact that space activities are potentially dangerous, and with NPS onboard, these risks increase.

2-2-1-Registration

When an object is launched into space, the first duty of launching state is about the registration of that object. It should be registered by the launching state on at least two of the following registries. At first, it should be entered on a registry maintained by the launching state, which is a state that launches or procures this process or from its territory or by its facilities a space object is launched (Perek, 1998). In addition, that object should be entered on one of the two registers maintained by the UN office for Outer Space Affairs (OOSA). The main purposes are identification of the space object which has caused the damage, pinpointing of the registry state for grounding responsibility, due to having ownership and Jurisdiction over it, for exercise of control and in the worst case, for recognition of liable state. In this respect, article VI of registration convention provides that if the available public information could not help to identify the registry state of a space object which has caused damage or has hazardous or deleterious nature, other parties to the convention who have monitoring and tracking facilities have the duty to respond as much as possible to the requests by either the state party or the UN Secretary General for assistance. That state should provide information about the time, nature and circumstances of this event. Article XI provides that the arrangements for this assistance shall be the subject of an equitable agreement with reasonable conditions.

The next point to consider is that the references to

states in this convention are deemed to be applied to an inter-governmental organization conducting space activities, which must declare its acceptance of the rights and obligations of this convention, and a majority of state members of that organization must be the state parties of this convention and the OST (Convention on international liability for damage caused by space objects, 1971).

2-2-2- Return and Rescue

Most of the objects launched into space will return to Earth in their due time. Therefore, the second duty of launching state is about the Return and Rescue of astronauts and space objects found in their territory (OST, Article (V)). The useful life of a Leo satellite is about five years and most of them re-enter the atmosphere within ten years. Some objects may be brought back deliberately, as in the cases of de-orbiting of Sky-Lab and Mir, or the return of US shuttle, ESA or Russian space craft. Yet, a launch may be unsuccessful and a space object may be lost on the Earth or in the space (Larrimore, 2007). The ARRA was designed to develop and give further explanations about this duty of states according to the OST for returning space objects. As such, the aim of this paper is paying attention to the state duties with respect to space NPS objects which must be observed by states to mitigate their potential risks which include:

- a. Rendering of all possible assistance to astronauts in the event of accident, distress or emergency landing and prompt safe return of astronauts (article. V).
- b. Returning objects launched into space, because the jurisdiction and control of a space object is retained by the states on whose registry it is carried. It means the ownership of the space NPS object is unaffected by being in space, by being on a celestial body or by its return to the Earth. Space objects, or their parts, found outside the territory of the state of registry are to be returned to that state by providing identifying data (article. VIII). So that all potential risks of NPS missions can be eliminated as much as possible.

The duties of state parties according to article 5 of ARRA upon the request of launching authority are:

1. Dissemination of information about an accident. (Article I (a)).
2. Notifying the launching authority of the space craft (Article. II). The state responsible for launching of an object can be an inter-governmental organization

(1968), Liability Convention (1972), Registration Convention (1974) and Moon Agreement (1976)", all of which should be observed by their parties in every space activity. Since some of the OST rules were passed into customary International Law, and all of the space faring nations ratified this treaty, this paper analyzes it separately.

2-1-Outer Space Treaty (OST)

The OST is a universal treaty open to all states (article (XIV.1)). As stated in Art. 38 of the 1969 Vienna convention on the law of treaties, a treaty rule can be binding upon the third state if that rule is recognized as customary rule of international Law (Vienne convention on the Law of treaties, 1969). Some of OST rules which were passed into customary International Law and must be applied to space NPS missions are as follows:

- a. Application of international law, including the charter of UN, in the interest of maintaining international peace and security and promoting international cooperation and understanding (article (III)). This means that space is not lawless.
- b. Outer space is not subject to national appropriation by any means (article (II)).
- c. The space is free for exploration and any use by all states, but must be for benefit of all nations and in the interest of them irrespective of their degree of economic or scientific development, and shall be the province of all mankind (article (I)). It means that emphasis must be on equitable and mutual cooperation in full compliance with legitimate rights and interest of all.
- d. States are responsible for their own national activities in space even those conducted by their private sectors. As state parties of this treaty have the duty to authorize and approve them. States are responsible for the space activities which they authorize, approve or conduct. This is the most important rule that must be observed in space NPS missions due to their potential risks for human and environment. In this respect, the OST recognizes that state parties bear "international responsibility" for their national's "activities" in space, and for assuring that such activities are carried out in accordance with the provision of this treaty which must be subject to authorization and continuous duty to supervise and monitor it by appropriate state party to the treaty (article (IV)). This means that every state party should create domestic legislation for licensing regulations and the conditions of permitting the use

of their territory by private individuals. So that, they can be responsible for acts attributable directly or indirectly to them especially in space NPS activities. Considering, trail smelter arbitration, it had been held that states are not responsible for activities of their nationals other than cases that they permitted the use of their territory in a way that caused damage to another state (Trail smelter arbitration (US V. Canada, 1938)). In this respect, the OST expressly establishes that state parties shall bear international responsibility for their national's activities in space, even if such activities are carried out by governmental or non-governmental entities. Inasmuch as they have authorized such activities and they have the duty to assure compliance with OST rules, and state parties should continually supervise those activities. The responsibility of the compliance with this treaty for the international organization of space activities shall be borne by that international organization and by the states who are parties to the treaty as well (article (VI)).

The next fact to be considered for space NPS missions is that according to articles VII and VIII each OST state party that launches or procures the mission, and each of them that from its territory or facility an object is launched to space, has the international liability for damage to another state party or its natural or juridical persons by such objects or its component parts on the Earth, in air or space.

e. According to article VIII of the OST, registry state of any launched object into space shall retain Jurisdiction and control over it and any personnel thereof while in space. The ownership of this object and its parts is not affected by launching to space, landing, construction in space or their return to the Earth, because space objects cannot be a *res nullius*. They remain the property of the registry state (Jasentuliyana, 1999).

f. The OST requires states to pursue space studies needed for conducting their space, exploration, so that to avoid their harmful contamination, any adverse changes in the Earth's environment resulting from the introduction of extraterrestrial matter, and where necessary to adopt "appropriate measures" for this purpose. This article prohibits any kind of contamination of the Earth's environment, even with the nuclear materials which are originally from the Earth (article (IX)).

For the purpose of NPS, thus, this paper is about to prove the relevance of responsibility of states to the space NPS missions. It has been found that according

1- Introduction

Nuclear power source (NPS) has been developed and used on space crafts, due to the limitations of hydrocarbon and battery power sources, to provide electrical power and thermal management required for deep space missions. Such missions include interplanetary missions to the outer limits of the solar system, for which solar panels were not suitable as a source of electrical power, because of the long duration of the mission and the great distances from the sun.

The first usual sources of NPS are nuclear fission reactors, which are similar to Terrestrial reactors being slightly different in the design of “core, cooling, moderation and control system”. In addition to space treaties, the documents of the International Atomic Energy Agency (IAEA) should be considered, to prevent the potential risks of the reactor. The advantage of reactor-based power plants is that they are capable of producing more power for space missions, than other sources of NPS. They produce intense heat that can be converted to electricity and used as power source for space craft systems and on-board electric propulsion systems, or can be harnessed directly for propulsion.

The second safe source of NPS for space missions is radioactive power source (RPS). This device is small and passive which uses the natural decay heat of radioisotope in the form of “Radioisotope Heating Units (RHUs)”, or converting the heat produced into electricity by “Radioisotope Thermo-Electric Generators (RTGs)” (Hannappel, 1984). An RTG unit does not involve nuclear fission as it is not a reactor and uses plutonium (PU-238) as fuel by converting the heat naturally generated from the plutonium isotope’s decay into electricity. As RTGs have no moving parts and the half-life of their pu-238 fuel is predictable, they are highly reliable power sources. Therefore RTGs are ideal for the missions in whom duration is extremely long or far from the sun that make other power sources, such as solar panels, untenable. RHUs are small and simple devices currently used to keep instruments warm in deep space missions. One disadvantage of RPS is it’s relatively low power output. Thus, each spacecraft must use multiple RTGs to provide enough power. In 1961, RTGs were used in the US space missions for the first time. In the Soviet space nuclear program, fission reactors were prioritized, which has been used on experimental and defense related satellites in low Earth orbit (The US have launched 44 RTGs aboard

25 missions). The industries and agencies in Europe gained some experiences with RPS, in the two co-operative space missions with the US: Ulysses and Cassini/Huygens (ESA, JPL. Ulysses operations index page, 2005) The US and Russian experiences with NPS in space show that it not only requires to be more developed, but also must become relatively flexible and the application scenarios should change to meet current space and nuclear treaty rules. Furthermore, safety steps should be taken before and after the occurrence of any accident, because the presence of radioactive materials or nuclear fuels in the form of space NPS can be of potential threat to people and the Earth’s environment (Mirmina, 2005). The main question that this paper is going to answer is that what is the role of space and nuclear treaty rules and environmental principles in mitigation of the potential risks of space NPS missions? The position is taken by this article is that duties stipulated in space and nuclear treaties and safety standards of IAEA is of primary importance for all activities involving NPS, so that safety as well as security and non-proliferation aspects are considered. As such, this paper aim is mitigation of the potential risks of space NPS missions by invoking state duties that must be observed in this mission properly. The treaties regarding liability and non-proliferation of global deployment capability should be considered as well (Reynolds, 2014). The ratification of some conventions and treaties for regulation of space activities and usage of nuclear energy indicates that states had realized the new kind of hazards namely the environmental threats generated by human activities. Some of these threats are more important due to their long lasting consequences, especially in the case of nuclear disasters which are an inevitable part of every space NPS mission, since it can endanger the present and future generations’ health and natural resources.

This paper focuses on international legal regimes of space and nuclear treaties and international environmental principles for mitigation of the potential risks of space NPS missions by analyzing both hard law (explicit, legally binding treaty provisions) and soft law (voluntary principles and declarations) as applicable to NPS.

2-International space law treaties and space NPS missions

The United Nations treaties concluded by COPUOS are: “Outer Space Treaty (1967), Rescue Agreement

Mitigation of Potential Environmental Risks of Space Nuclear Power Sources (NPS) Missions in International Law

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Abstract

Nuclear power source (NPS) is the only sustainable power source capable of providing the energy required for deep space activities. This is due to the limitation for hydrocarbon fuel, battery power and even solar power in deep space missions conducted far from the sun. In this paper, space treaty rules which can help mitigate the potential risks of nuclear fission reactors and radioactive power sources (RPS) are analyzed, using a descriptive method. It has been found out in this paper that registry and launching state are liable to compensate for any damage caused and environmental pollution. The position is taken by this paper is that safety of this missions as well as mitigation of environmental pollution is very important. In every high risk space activity, appropriate safety steps as well as environmental principles and nuclear treaty rules should be observed before and after the occurrence of any accidents.

Key words: Nuclear power sources for space (NPS), International law, space debris, space treaties, Committee on the peaceful uses of outer space (COPUOS), nuclear treaties, and environmental principles.

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