LEGAL CONTROL OF THE USE OF NUCLEAR POWER SOURCES IN OUTER SPACE: ELEMENTS FOR A REVISION

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Abstract

The legal control of nuclear power sources (NPS) regulates the use of an advanced technology necessary for the exploration of outer space but which nevertheless presents potential hazards. The legal control of the use of NPS results from international space conventions and, since 1992, from the *Principles Relevant to the Use of NPS* and established preventive and emergency measures, and a liability and compensation regime. Several areas call for improvement to increase efficiency and comprehensiveness of the control. Proposals for revision encompass reinforcing the *1992 Principles* (scope, applicability, binding force etc.). Other proposals want to integrate to the existing regime the principles elaborated for terrestrial applications of nuclear energy. It is also broadly recognized that an efficient control must take into consideration the space debris issue. Modalities of the revisions proposed as well as their potential framework vary as opinions differ as to the extend of the revision to be conducted.

Résumé

Le contrôle juridique de l'utilisation des sources d'énergie nucléaire (SEN) dans l'espace réglemente l'utilisation d'une technologie très avancée, nécessaire à l'exploration de l'espace, néanmoins dangereuse pour la communauté internationale. Le régime juridique actuel résulte des conventions spatiales et, depuis 1992, des *Principes Relatifs à L'Utilisation des SEN*, qui ont établi des mesures préventives, d'urgence, ainsi qu'un régime de responsabilité. Plusieurs domaines demandent cependant à être améliorés, tels le champ d'application et la force juridique des *Principes de 1992* ou encore l'intégration des principes juridiques développés pour les applications nucléaires terrestres aux *Principes* de 1992, et la prise en considération des problèmes liés aux débris spatiaux. Les modalités de révision proposées varient ainsi que son cadre car les opinions divergent quant au forum mieux à même de réaliser une réforme exhaustive du système juridique applicable aux SEN.

"Comparing the number of American and Soviet satellite missions with nuclear power sources on board and the number of accidents which have become known to the general public it can be assumed that the accident rate of both space powers is equal and lies between 15 and 20%."[1]

The legal control of nuclear power sources (NPS) intends to regulate an advanced technology which, albeit useful for the exploration of outer space, presents hazards that may affect the entire world community. The elaboration of rules relating to the use of NPS was done in a dual approach. On the one hand, it provided a regime of prevention by focusing on the (difficult) elaboration of specific safety measures. On the other hand, a regime of assistance and of responsibility was also set up, in case of emergency or accidents. As stated by the then Ambassador and Permanent Representative of Canada to the United Nations (UN) W. Barton, "the utilization of this technology in outer space calls for special precautions and a special regime of international cooperation designed to ensure the safety and integrity of the human environment."[2]

Conscious of the dangers represented by nuclear power sources (hereinafter NPS) in outer space, the international community agreed, in 1992, on a set of principles governing the use of NPS (integral text of the Principles reproduced in Annex I). The first step took a long time to be taken, and while taking it, several States were

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1 M. Benkö & J. Gebhard, "The Use of Nuclear Power in Outer Space" in M. Benkö, W. de Graaff & K-U. Schrogl, eds., *International Space Law in the Making - Current Issues in the UN Committee on the Peaceful Uses of Outer Space, Forum for Air and Space Law*, vol.1, (Paris: Frontières, 1993) at 23.

2 W. Barton, "The Use of Nuclear Power Sources in Outer Space" (Statement to the Scientific and Technical Subcommittee of UN COPUOS, 16 February 1978), UN GAOR UN Doc. A/AC.105/C.1SR.188 (1978).

already conscious that a second step would be needed in the near future to improve the newly adopted *Principles*. Improving the UN *Principles* includes updating their content in the light of technological developments and including other potential uses of NPS such as propulsion, voluntarily left out at the time of the adoption of the *Principles*. Several States have already introduced working papers in which the necessary revisions are highlighted; however, to date, although the revision was to start two years after the adoption of the *Principles*, it is not likely to happen within the next year as in 1997, the Committee on Peaceful Uses of Outer Space postponed a possible revision at a later stage.

Following the Barton Declaration[3], Canada along with 8 other countries[4] proposed to the Scientific and Technical Subcommittee (STSC) that a Working Group of experts be constituted and consider "Questions Relating to the Use of NPS in Outer Space". If most delegations proved to be in favor of this proposal, the former Soviet Union opposed it. Nevertheless, a Working Group was eventually set up to examine the technical aspects and the safety measures concerning the use of NPS in Outer Space. The purpose of the study was to provide a technical base for a multilateral regime of standards related to the use of NPS. Consequently, the STSC met in 1979, 1980 and 1981 and from 1984 to 1991. However, concerning the legal issues, it is interesting to see the evolution of the States' desiderata through the wording of the matter on the Agenda of the Legal Subcommittee (LSC). In 1979, the question was referred to as "various questions" thus indicating that the focus was put more particularly on the technical and scientific aspects, contrary to the intention of Canada[5] and a certain number of States which wanted a parallel study of the existing legal instruments. Nevertheless, following bilateral negotiations between

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3 *Ibid.*

4 The countries were Australia, Colombia, Egypt, Ecuador, Italy, Japan, Nigeria and Sweden, 27 February 1978, UN GAOR UN Doc. A/AC.105/C1/L.103.

5 S.Courteix, "Questions d'Actualité en Matière de Droit de l'Espace", XXIV AFDI (1978), 914.

Canada and the Soviet Union, the COPUOS recommended that the LSC envisages during its next session a:

> "Review of International Law relevant to Outer Space activities with a view to determining the appropriateness of supplementing such Law with provisions relating to the Uses of NPS in Outer Space."[6]

Canada submitted another Working Paper[7] in 1980 to the LSC, which, contrarily to the Soviet's, developed the idea that existing international provisions needed to be completed. The matter was consequently submitted once again to the COPUOS and the United Nations General Assembly (hereinafter UNGA) which modified the title of this item to "Consideration of the possibility of supplementing the norms of International Law relevant to the Uses of NPS in Outer Space."

A new Working Group was constituted within the Legal Subcommittee to examine the question. During two consecutive years Canada modified the content of its Working Paper not succeeding, despite its efforts, in seeing it agreed upon due to different opinions[8]. Following the 1983 consensus on the Principle on *Notification of Re-entry*, Canada insisted again on the fact that the LSC be given a precise mandate on the elaboration of *Principles* concerning the use of NPS in Outer Space. In 1985 the title of the item was changed to "Elaboration of draft principles relevant to the use of NPS in Outer Space."[9]

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6 UN GA Res.34/66, UN GAOR 1979, UN Doc.A/34/20 at para.51.

7 UN COPUOS, *Report of the Legal Subcommittee on the Work of its 19th Session*, UN GAOR UN Doc.A/AC.105/271 (1980), at paras. 43-52 and *Working Paper submitted by Canada on the Use of Nuclear Power Sources in Outer Space*, UN GAOR, Annex III, UN Doc.A/AC.105/C.2/L.126 (1980).

8 S. Courteix, "The Legal Regime of NPS, a Problem at the Cross Roads of Nuclear Law and Space Law" (1991) *34th Colloquium on the Law of Outer Space* 117 at 124.

9 UN GAOR, Res.40/162 (16 Dec. 1985) at para. 4(b).

Following the consensus of 1990 on Principle 3, the item title was modified for the last time to "Elaboration of draft principles relevant to the use of NPS in Outer Space, in view of a definitive mise au point."[10]

The present paper, after a presentation of the nuclear power sources used in Outer Space (nuclear reactors and radioisotopes), will focus on the applicable legal regime forming the framework to activities involving nuclear power sources in outer space and which involves conventions (indirect regulation) and the *Principles* of 1992 (direct regulation). Fast development of new technologies and adaptation of new requirements in other conventions or international recommendations call for a revision of the *Principles* so as to avoid their becoming an obsolete framework to fast evolving activities. Some authors have proposed more than a mere revision of the *Principles* and would indeed see more benefits in integrating the revision of the legal control of the use of NPS in outer space within a forum which would address all outstanding issues relating to space activities.

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10 UN GAOR, Res.45/72 (11 December. 1990) at para. 4(a).

PART I: NUCLEAR ENERGY SOURCES USED IN OUTER SPACE

The first Part describes the sources of nuclear energy used for space activities along with the risks entailed by such use, both in outer space and at launching site, should NPS be ever used for propulsion.

A. Technical Characteristics

The use of NPS concerns two essentials aspects of spacecraft operation: propulsion and energy generation of the spacecraft. Nuclear power sources have so far only been used as power sources and heat supply for on-board equipment although other uses are technically feasible such as propulsion or orbit correction. At a certain level of energy requirement and for missions too remote from the reach of the sunrays, nuclear power generation is the sole available source of energy for spacecraft operations and electrical power.

1. Propulsion

It is important to note that the selection of one propulsion system rather than the other is based on the propulsion functions required (e.g. orbit insertion, orbit maintenance and attitude control), and on the system options, i.e., if combined or separate propulsion systems for orbit and attitude control will be used, etc.[11] Space propulsion systems encompass three types of maneuvers:

(1) Lift of the launch vehicle and its payload from the launch pad and placement of the payload into a low Earth orbit (hereinafter LEO);

(2) Transfer of payloads from LEOs into higher orbits (GEO) or into trajectories for planetary encounters;

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11 R.L. Sackheim, R.S. Wolf & S. Zafran "Space Propulsion Systems", *Engineering Core Lecture Notes*, I.S.U. (Sum.Sess.1994) 636 at 637.

(3) Provide thrust for attitude control and orbit corrections.[12]

The selection of a particular propulsion system is based on the performance requirements. The most common propulsion systems are:

(1) Cold gas propulsion systems are inexpensive however rarely used due to their low performance.

(2) Solid propellant have been used extensively for orbit insertion however, another system must be used for orbit maintenance and attitude control.

(3) Liquid systems are divided into monopropellant which provide good orbit maintenance and attitude control functions but lack performance for orbit insertion; bipropellant and dual mode which can provide all three functions described above but are more complex.

Nuclear propulsion reactors present two major advantages: (1) a higher specific impulse compared to conventional chemical rockets and (2) a propulsion system where no other system is available. The first advantage refers to the payload that can be lifted up, which would be higher should nuclear propulsion be used. The second advantage refers to available propulsion systems for missions launched from outer space. Indeed, if Mars based settlements are to be installed, missions going from this settlement for deep-space missions or to explore the solar system or other planets would have to use nuclear power. Several projects have been undertaken by the main space States such as the US. The Los Alamos national laboratory started to study a project of engines which would allow the launching of

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12 *Ibid.* at 638.

payloads from low earth orbit to more distant locations.[13] Moreover, the US started developing project "Timberwind" within the Strategic Defense Initiative (SDI) undertaken within the Department of Defense programmes. The project consisted of a nuclear rocket using a Particle Bed Reactor which would have allowed nuclear propulsion of spacecraft, thus implying the actual use of a nuclear device at launch time, and not, as currently done, once the space vehicle achieves its orbit.[14] This new technology would give a higher specific impulse thus allowing to lift payloads of about 70 tons up to a Low Earth Orbit (LEO), whereas the highest performing American rocket can only lift payloads of up to 20 tons. This force of propulsion would also shorten travel time of Astronauts to Mars.[15] This project, surrounded by a certain amount of controversy was therefore dropped.

2. Spacecraft power source types

Electrical power subsystems on board a spacecraft provide, store, distribute, and control the spacecraft electrical power. Power generally needed on board a spacecraft may be provided by different sources, depending on the mission requirements.

- Solar photovoltaic power source uses sunlight cells directly converted to electricity; it is the normal power source for nearly all spacecraft in Earth orbit.

- Solar thermal dynamic uses solar heating to drive an engine,

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13 W.J. Broad, "New Plans for Space Reactors Raise Fears of Nuclear Debris" *New-York Times* (18 October 1988).

14 W.J. Broad, "Rocket Run by Nuclear Power Being Developed for "Star Wars" *New-York Times* (3 April 1991) A1, C1.

15 J.A. Asker, "Particle Bed Reactor Central to SDI Nuclear Rocket Project" *Aviation Week and Space Technology* (8 April 1991).

e.g., a steam turbine, which then produces electricity.

- Radioisotope thermoelectric generators (RTGs) use a direct thermal to electric conversion using radioactive decay of radioactive isotopes (typically plutonium) as a heat source. RTGs also require a converter to produce electricity from the nuclear heat sources. RTGs' energy is principally used on interplanetary missions far from the sun and with long life requirements. These sources are between 1 and 10 kg of plutonium-238 (USA) or of plutonium-210 (former Soviet Union). There are other types of RTG fuels which were tested by the US such as Cerium 144, Polonium 210, Curium 242 etc., but Plutonium 238 (Pu-238) is the most performing fuel due to *inter alia* its long half-life (87.5 years, i.e., the time it takes for one-half of the original amount of fuel to decay), low radiation emissions and high power density. Plutonium is usually on board spacecraft requiring 1 kilowatt (kw) or less. The availability of Pu-238 for future space missions has been a continuous concern for the US as for the past thirty years, the production and processing of Pu-238 has been accomplished as a by-product of materials for nuclear weapons. The recent changes in the US nuclear weapon programmes will eliminate the traditional capability to produce Pu-238. Alternative facilities to provide a continuing Pu-238 production and processing capability for future space applications are being investigated as well as the possibility to purchase Pu-238 from foreign sources such as Russia.[16]

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[16] R.G. Lange, "A Tutorial Review of Radioisotope Power Systems" in M.S. El-Genk, ed., *A Critical Review of Space Nuclear Power and Propulsion 1984-1993*, (New-York: American (continued...)

... Since 1961 the USA have launched 37 RTGs on 25 spacecraft (see Annex II). RTGs have been used for both civilian and military missions in outer space by the US, e.g., in naval navigation or communications or for Viking Mars and Apollo missions as well as for deep-space probes such as Pioneers and Voyagers.[17] The more recent NASA missions Galileo to Jupiter and Cassini to Saturn use RTGs.[18] The US Department of Energy's budget cutbacks have put in jeopardy the continuation of development of RTGs. Indeed, NASA is exploring new technologies that can supply nuclear electrical power for interplanetary probes which would allow to cut the power loads required by the spacecraft in order to lower the costs, the isotope levels and to extend the life of the systems. NASA is therefore studying with the Department of Energy a new radioisotope generator program.[19] See list of future US launches of RTG-powered missions in Annex IV.

- Nuclear reactors use power to drive an engine to create electricity, similarly to solar thermal dynamic. Nuclear reactors derive their thermal energy from a controlled fission process. The fissioning core produces heat which goes through a converter and is then converted to electricity. The process is similar to nuclear power station on Earth.[20] The nuclear source is usually 30 kg of uranium-235.[21] In fact, Principle 3 of the *Principles* Relevant to the Use of Nuclear Power Sources in

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[16](...continued)
Institute of Physics, 1994) 1 at 5.

[17] J.A.C. Clayton, "Nuclear Power Sources for Outer Space: Political, Technical and Legal Considerations" (1989) *32d Colloquium on the Law of Outer Space* 286.

[18] T. Foley, "Space Nuclear Power Faces Bleak Future" *Space News* (16-22 January 1995) 6.

[19] L. David, "NASA Eyes New Power Sources" *Space News* (February 13-19, 1995) 7.

[20] J.K. McDermott, "Spacecraft Power Systems" in *Engineering Core Lecture Notes*, *supra* note 11, 391 at 409.

[21] J. Hecht, "Hungry for Power in Space" *New Scientist* (8 July 1989) 51 at 54.

Outer Space, in section 2.4, clearly states that "Nuclear Reactors shall use only enriched uranium-235 as fuel." Uranium-235 used for reactors has a half-life of 713 million years and generates between 5 and 20 kilowatts of electricity. The energy supply of the former Soviet Union's RORSATS (Radar Ocean Reconnaissance Satellites) derived from uranium.

... Since 1961 the US have launched several reactor-powered spacecraft (see Annex III).

Further experimental programs such as the space nuclear reactor called SP-100 were designed to provide technology for advanced NASA missions into the 21st century. The program was exploring more efficient and light weight ways to create electricity in space (US space nuclear program) but this program was also dropped.[22] The Multimegawatt Program is another project developed between 1985 and 1990 within the Strategic Defense Initiative and later abandoned due to financial constraints and to priority changes.[23]

The former Soviet Union developed the surveillance radars RORSAT[24] which operated in low, short-term orbits. Since 1967, the former Soviet Union has orbited approximately 33 thermoelectric reactor power systems as power sources for the surveillance radars (RORSATS). Nine were launched between 1983 and 1988. Power level range from several hundreds watts to a few kw. Limited information is available on the details of the RORSATS power systems. A different type of reactor

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22 G.L. Bennett, "Developing a Realistic Nuclear Policy" *Space News* (6-12 February 1995) 15.

23 D. Buden, "Summary of Space Nuclear Reactor Power Systems (1983-1993)", in El-Genk, ed., *supra* notes 16, 21 at 70.

24 RORSAT: Radar Ocean Reconnaissance Satellite.

started to be tested in 87-88 and space tested, i.e., COSMOS 1818 and COSMOS 1867 using what the US call TOPAZ I. A number of design modifications were added to meet US safety standards which include among others, the inclusion of a re-entry thermal shield to avoid breakup in the event of re-entry and a built-in safety feature to shut down the reactor, if the reactor leaks and the control system does not shut down the reactor. TOPAZ nuclear reactor is nevertheless facing also financial constraints and the Russians have said not to be able to take the project beyond its initial stage. The Russians are however offering to transfer the technology and form a working group with representatives from other nations to develop international projects since international cooperation appears to be the way to keep space nuclear work alive.[25] On the American side, it has been advocated to use TOPAZ II instead of developing programs such as the SP-100, proposal strongly criticized on the ground that TOPAZ II is low-powered, heavy, has never been flown and is based on outdated technology. It has also been argued that it lacks the demonstrated lifetime required for long-term planetary missions and that the US should keep a national nuclear policy to support future outer planetary missions[26] since beyond Cassini, neither NASA nor the Defense Department has a firm requirement for more nuclear power devices for space applications. It should however be noted that NASA has shown interest in a smaller, more efficient nuclear power source for a Pluto Express mission tentatively planned for a 2001 launch.[27] If nuclear devices are the only means to succeed for deep-space missions the US will have problems participating in them and also are about to deviate from Clinton's initial space program regarding the exploration of the solar system.

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25 T. Foley, "Space Nuclear Power Faces Bleak Future" *Space News* (16-22 January 1995) 6.

26 G.L. Bennett, "Developing a Realistic Nuclear Policy" *Space News* (6-12 February 1995) 15.

27 T. Foley, "Space Nuclear Power Faces Bleak Future" *Space News* (January 16-22, 1995) 6.

3. Advantages of the Use of NPS Compared to Other Sources of Energy

Over the last decade, changes in space technology have increased the level of power output required in outer space missions. At the same time, the life expectancy of these missions has also improved, therefore requiring a simultaneous increase of the life span of space power generation. Electric power is mainly necessary for spacecraft sub-systems such as attitude control, communications and command, as well as operations of various equipment on board. Thus far, solar cells, chemical batteries and other fuel cells, have been the non-nuclear sources of energy used in space missions. Photovoltaic system (solar cells) is the conventional and the cheapest source of energy.[28] As described above, it uses solar panels in order to capture solar rays which are then converted into electric power. Yet, this system presents several drawbacks. Indeed, in order to increase the power output, solar arrays may be built larger while increasing the difficulty of deploying the array and the vulnerability of the system to outer space environment (e.g, natural atomic oxygen, high energy charged particle bombardment meteorites, man-made debris..).[29] On the other hand, improving the protection would imply covering the system with a thick glass cover, therefore increasing its weight and the probability of deterioration of the system specific power.

On the contrary, nuclear power sources come in relatively compact sizes, are light in weight, and can operate in remote places from the sun. This particular element has been clearly recognized in the *1992 Principles Relevant to the Use of Nuclear Power Sources in Outer Space*. Indeed, the Preamble recognizes that "for some missions in Outer Space, nuclear power sources are particularly suited or even

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28 W. Boyer, "Solar Energy is Mainstay for Future Space Projects", *Space News* (9-15 July 1990).

29 U. Ortabasi, "A hardened Solar Concentrator System for Space Power Generation: Photovoltaic Cavity Converter (PVCC), Proc. 42nd Congress of the International Astronautical Federation (5-11 October 1991).

essential due to their compactness, long-life and other attributes." NPS present the great advantage of being inherently tolerant to external radiation (such as the Van Allen Belt thus preventing system degradation). In a paper presented at the 42nd Congress of the International Astronautical Federation, U. Ortabasi[30] presented a project on a Photovoltaic Cavity Converter, more resistant to space hazards which would perform well with respect to the capacity of output of the system. He nevertheless admits that "in applications like the Van Allen Belt or Solar Probe missions where charged particles induced radiation damage to the cells and away components is extreme or plasma effects degrade the system performance severely" the resistance would not suffice. On the other hand, the global amount of energy provided by photovoltaic panels is not sufficient for many applications in outer space.

Thus, for the exploration of planets, or if manned bases on Mars or on the Moon are to be installed, the extended night periods undergone in these areas imply that solar energy is of little value compared to nuclear power output capacity. Regarding the Space Station, NASA officials confirm that solar energy supply, albeit sufficient at the beginning, will not be able to meet the requirements for manufacturing, science experiments and life support, as the Station expands. The evaluated amount needed is of 75 kw therefore requiring the use of NPS.

B. Hazards

The necessity to regulate the utilization of NPS, mainly resulted from the fact that accidents involving NPS would have irreversible and severe consequences, such as contamination of the Earth, which would affect a large part of the world population and the human environment. Contamination is the essential danger resulting from the use of nuclear devices. Incident/accident may occur either before

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30 U. Ortabasi, *Ibid.*

or after the spacecraft achieves its orbit, that is, either in the atmosphere or in outer space. NPS also interfere with scientific experiments such as the Gamma Ray observations.

1. Contamination of the Atmosphere

1.1 Contamination Due to Accident during Launch or Ascent of a Nuclear Powered Vehicle

The probabilities[31] and the list of previous incidents/accidents show that the danger is real despite the safety measures space Nations have included in the design of NPS-powered spacecraft (see *infra*, Part II(B1) and concern both reactors and RTGs.

- **RTGs:**

The first incident occurred in April 1964 where a US RTG-powered navigational satellite, Transit-5BN-3, failed to reach its orbit and disintegrated, as it was designed to, over the Indian Ocean. It dispersed 17,000 curries of plutonium-238 at high altitude (50 km), increasing the global radioactivity burden from all plutonium isotopes by about 4%.[32]

In 1968, another US meteorological satellite, Nimbus B-1, powered by two RTGs (SNAP19-B2),[33] fell into the Ocean, off the coast of California due to a launch failure. Its two RTGs were recovered 5 months later, with no evidence of radioactive leak.

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31 *Supra* note 1.

32 S. Aftergood, "Towards a Ban on Nuclear Power on Earth Orbit" *Space Policy* (February 1989) 25 at 40.

33 SNAP: System for Nuclear Auxiliary Power. This program included both Reactors (denoted by even numbers) and RTGs (denoted by uneven numbers).

The latest accident occurred in November 1996 when the Mars Probe launched by the Russian Federation fell the day after the launch, and its exact location is still an issue of discussion.

- **Reactors:**

Several incidents involving reactors have also been reported. Out of 30 reactor-powered satellites launched mostly into low Earth orbit by the former Soviet Union, at least two RORSATS underwent launch failure, first in 1969 and in 1973, where it fell into the Pacific Ocean, near Japan.

Nuclear reactors are usually started once the satellite achieves a stable orbit, not before. Although this precaution does not prevent a risk of contamination if the spacecraft is damaged before reaching its position, it is considered safer. Thus, the SP-100 reactor mentioned earlier had been equipped with two independent features to maintain it inoperable until it reached its orbit, and in case of a launch accident.

The SDI project, "Timberwind", was developed to be used for propulsion. As mentioned earlier, this type of space nuclear rocket propulsion would replace conventional chemical rockets as the specific impulse given to the spacecraft is higher. The project was severely criticized by the Federation of American Scientists since it increased radiation risks during the ascent. S. Aftergood, a senior research analyst with the Federation opposed in an interview given to the New York Times, where he said that the rocket "was going to be putting out a cloud of radioactive materials"[34] from its exhausts into the earth's atmosphere. This particular argument goes against the views of other experts who agree to say that the risk of radioactivity contained in the rocket exhausts would not be at a dangerous level. On the other hand, such a project could prove useful and less dangerous in the case of transfer or launch of spacecraft from a space-based station to another planet.

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[34] Aftergood, *supra* note 32.

The risk to the environment is an argument advanced even for conventional vehicles and satellites. Several studies sponsored by the US Air Force showed that launches and re-entries of space hardware was detrimental to the ozone layer. One of these studies conducted in November 1994 by the Aerospace Corp. (US Air Force) titled "Stratospheric Ozone Reactive Chemicals Generated by Space Launches Worldwide" shows that space hardware reentering the atmosphere produces materials which, combined with elements of the Earth's upper stratosphere, contributes to ozone depletion. Another study titled "Effects of the Impact of Deorbiting Space Debris in Stratospheric Ozone" shows that the global effect exists but not on a significant level globally. The US Shuttle is apparently the largest polluter.[35]

The fear concerning the use of NPS while the spacecraft is still in the atmosphere is based on environmental concerns. However, the problems that may result from the use of NPS extends to other fields, as soon as the spacecraft "enters" outer space. Space militarization is one of the preoccupations of opponents to nuclear energy in outer space, while scientists argue that this energy interferes with certain scientific experiments.

1.2. Re-entry of NPS due to Malfunction

Risks in outer space encompass the possible contamination of terrestrial territories due to the re-entry of a nuclear powered spacecraft or pieces thereof. This section refers to malfunctioning spacecraft which, deorbitated, and having gone out of control, re-enter the atmosphere. Such type of malfunction concerns both reactors and RTGs.

In April 1970, the USA Apollo 13 mission aborted and its lunar lander fell into the

[35] L. David, "Studies Analyze Ozone Loss from Launches Re-Entries" *Space News* (6-12 February 1995) 5.

Pacific Ocean. Its SNAP-27 power-supply was retrieved and, fortunately, no contamination followed. Moreover, the USSR unmanned Moon probes launched in September and October 1969 re-entered the atmosphere after a few days in orbit and this time measurable amounts of radioactivity were detected.

Not of the least were the COSMOS incidents. COSMOS 954, equipped with uranium, was launched in 1977 on a maritime observation mission into a low Earth orbit. After the completion of the mission, its nuclear core was to be boosted up to a higher orbit where it would decay, become inert over a period of 600 years. However, the satellite malfunctioned and, going out of control, eventually re-entered the atmosphere, spreading 65 kg of radioactive materials over the Canadian Northwestern Territories.[36] This incident gave impetus to international concern regarding the use of NPS. The matter was subsequently placed on the agenda of the United Nations Committee on the Peaceful Uses of Outer Space (COPUOS). Other incidents involving COSMOS satellites occurred in 1983 and in 1988. In the first case, COSMOS 1402 re-entered the atmosphere over the Indian Ocean and its nuclear core disintegrated over the Atlantic Ocean. However, after the 1978 accident, COSMOS system had been redesigned to jettison the reactor core upon completion of a mission, to facilitate disintegration in the high atmosphere in the event of re-entry. Yet, this did not prevent a third incident involving a COSMOS to occur. COSMOS 1900, another military reactor, was launched in 1987 and was part of the series redesigned after the 954 accident. COSMOS 1900 suffered a boost problem that left the spacecraft on an orbit lowered than planned after its launch. The satellite itself burnt up on its way down to the Earth and in 1988, an automatic system shut down the nuclear reactor and transferred it to a higher orbit, thus allowing the radioactive materials to decay to a safe level before reaching the atmosphere. In 1995, the same COSMOS 1900 was suspected by the US of leaking

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36 B.A. Hurwitz, "Reflections on the COSMOS 954 Incident"(1989) *32d Colloquium on the Law of Outer Space* 348 at 354.

reactor coolant.[37] As mentioned above, the spacecraft was designed to eject the radioactive fuel core into higher orbits in case of malfunction. The spacecraft is composed of the main body, the coolant supply and the reactor. When the nuclear reactor was jettisoned to a safe orbit, the main body and the coolant supply were left behind. The coolant is sodium potassium in liquid metal form that have extremely long lifetime. The identified leak is in the form of tiny spheres at an altitude of 900-1000 km but there is no indication as to whether the material is radioactive.[38] The reason of this leak is still not known but this illustrates how important design of spacecraft is in order to make them remain intact even when they become non-operational. This type of nuclear powered spacecraft evolves in low Earth orbit whereas the US satellites Nimbus and Transit orbit at higher altitudes, on long-term orbits (several centuries) therefore allowing their radioactive generators to become inert.[39] In case of re-entry they would then not represent a danger of contamination.

Two major associations of scientists opposing the use of NPS, argue that NPS should be internationally banned from low earth orbit. The Committee of Soviet Scientists Against the Nuclear Threat and the Federation of American Scientists wrote a joint proposal in which they stated that "the ban on reactors in orbit would not prevent the use of nuclear power for deep-space scientific or exploratory missions...".[40] The SP100 US project had been designed to operate in higher orbits and remain intact in the event of a launch accident as mentioned previously. Although it was to orbit on LEO, it was equipped with redundant systems for

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37 The Lincoln Laboratory's Haystack radar system is operated by the M.I.T.

38 L. David, "Russian Satellites Suspected as Space Debris Source" *Space News* (13-19 February 1995) 5.

39 Y. Rébillard, "Débris Spatiaux: vers une meilleure connaissance et une maîtrise concertée du problème" (1990) Revue française de droit aérien.

40 "A joint Proposal to Ban Nuclear Power in Earth Orbit", signed by F. von Hippel on behalf of the Federation of American Scientists and R. Sagdeev on behalf of the Committee of Soviet Scientists Against the Nuclear Threat [undated].

shutdown and expulsion to a higher and safer orbit upon completion of the mission and, in case the previous means failed to prevent its descent towards the Earth, another system was planned to permit a safe re-entry to avoid the scattering of radioactive debris all through the atmosphere.

2. Collision with Orbiting Space Debris

NPS-powered spacecraft may, as any other spacecraft evolving in outer space, collide with other orbiting debris which would result in (1) increasing the number of NPS which could re-enter and pollute the atmosphere and (2) increase the overall number of orbiting debris.

A "space debris is a man-made Earth-orbiting object which is non-functional, with no reasonable expectation of assuming or resuming its intended function or any other function for which it can be expected to be authorized, including fragments and parts thereof".[41] Every object launched in space is bound to eventually re-enter the Earth's atmosphere, escape from Earth orbit into deep space or remain in Earth Orbit. Collision with a debris produces either destruction of both the debris and the collided spacecraft or might considerably degrade the mission. Collision of a space object containing nuclear power sources and a debris present a high degree of risk as such collision could result in the re-entry of the object with nuclear power sources on board or component parts thereof. The problem of space debris is not new but took time to be fully acknowledged by States (see *infra* Part III (D)). Information regarding the former Soviet Union has led to significant revelation such as for example, that the first GEO breakup occurred in 1978 and that COSMOS 1275 had probably suffered a break-up by collision, in 1981.

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[41] *IAA Position Paper on Orbital Debris,* UN COPUOS, Annex, UN Doc. A/AC/105/593 (1994) 22 at 22 [hereinafter IAA Position Paper].

Debris are continuously tracked by the US Space Command's Space Surveillance Network (SSN). Objects have been officially cataloged[42] and the highest population of debris is found in LEO and GEO. The amount of debris in the 1-10 cm range is estimated to be between 35,000 and 150,000 and particles larger than 1 mm are probably more that 1,000 times the catalogued population.[43] However, the collision risk is higher in LEO than in GEO because of the higher relative velocity and the smaller regional volume. Compared to meteoroids, man-made debris are much more dense materials, of larger size, and as a result, are now considered the primary particular design environment for manned and unmanned space systems. More than 40% of trackable objects are fragments of rockets upper-stages and spacecraft and result from explosions. Only 6% of catalogued objects are operational space objects, the rest are fragments, space debris.[44] A measurement campaign conducted by the Haystack Radar (US) during 24 hours showed that current space debris models overestimate the number of debris at lower altitudes (300-500 km) whereas the number is underestimated at higher altitudes (800- 1,000 km).[45] According to ITU, there are about 322 active and derelict spacecraft and 11 rocket bodies and other associated objects in the region of GEO (effective Oct. 91). Most of these objects are no longer under active control of the original operators.[46]

Since 1981, it has regularly been advocated that the development of inexpensive launch systems would find a solution should high-level nuclear waste be disposed of in space instead of underground. Although the idea started in 1981 (American

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42 Cataloged objects are considered to be objects larger than 10-50 cm in diameter for LEO and 1 m in diameter in higher orbits (GEO and HEO).

43 UN COPUOS, *Scientific and Technical Presentations to the Scientific and Technical Subcommittee at its 38th Session*, UN GAOR UN Doc.A/AC.105/606 (1995) para.21 at 5 [hereinafter UN Doc. A/AC.105/606].

44 *Ibid.* UN Doc. A/AC.105/606, para.31 at 6.

45 UN Doc. A/AC.105/606, *supra* note 43 para.6 at 24.

46 *Ibid.*

Institute of Aeronautics and Astronautics/Space Systems Technical Committee) it has never received strong support from either the governments or the industry therefore the risk is remote. The supporters argue that disposing of nuclear waste in outer space would provide a justification for massive investments in space technologies rather than investing in manned missions to Mars, due to the fact that the public has long lost its interest in "second hand" experience of space.[47],[48]

3. Interference with Scientific Experiments

Finally, another argument against the use of nuclear power sources in outer space opposed by scientists concerns the interference that active NPS in space cause to some observations or scientific experiments such as Gamma Ray observations. These observations are of major importance for the study of Astronomy phenomena (e.g, quasars, black holes, supernovas, and neutron stars). The problem arises from the fact that reactor-equipped satellites, as RORSATS are, emit Gamma Rays from fission fragment in the reactor's core. These phenomena in particular appeared after the launch of the Solar Maximum mission in 1980, and even more in 1987 due to interruptions of the solar missions several times a day by newer RORSATS. The same problem affected the Japanese Ginga satellite launched in 1987, which, reportedly, spent "about 40% of its time observing and transmitting garbage".[49] However, it has been argued to oppose this claim that man-made emissions and celestial signals may be differentiated although it is time consuming.

In Part I we examined the various technical aspects of the use of nuclear power sources in outer space, pointing out the numerous risks attached to their utilization.

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47 J. Coopersmith, "Dispose of Nuclear Waste in Space" *Space News* (13-19 February 1995) 15.

48 P.H. Diamandis, "Attention CEOs", *Space News*, (3-9 July 1995) at 15.

49 *Supra* note 13.

In order to regulate and control such utilization, the international community started long ago to include various provisions in conventions and treaties relating to NPS but the first regulation directly dealing with the use of nuclear power sources was only adopted in 1992.

Part II: The Legal Framework Applicable to Activities Involving the Use of Nuclear Power Sources in Outer Space

Part II (1) addresses treaties and conventions whose provisions form the basis, the applicable regime to the use of NPS in outer space and (2) analyzes the areas/measures relating to the uses of NPS addressed, be it directly or indirectly, by international instruments.

A. Basis for the legal Control of the Use of NPS in Outer Space

The present section describes the legal framework in which activities involving the use of NPS take place.

1. Legality of the Use of NPS

The use of NPS is lawful: The use of NPS in outer space has never been forbidden and the aim of the legal framework covering their use is not to authorize it but instead, recognizing the usefulness of NPS as well as its potential dangers, to regulate such use in order to guarantee maximum safety and security. The necessity of the use of NPS is recognized in the Preamble of the *Principles Relevant to the Use of NPS in Outer* Space, adopted by consensus on June 26, 1992 by the United Nations Committee on Peaceful Uses of Outer Space.[50] Indeed, paragraph 1 of the Preamble reads as follows:

> Recognizing that for some missions in outer space nuclear power sources are particularly suited or even essential due to their compactness, long life and other attributes.

States never requested a total ban on the use of NPS in outer space even in the moments following the COSMOS 954 incident where, had the satellite fallen on

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[50] *The Principles Relevant to the Use of Nuclear Power Sources in Outer Space*, adopted on 14 December 1992 (UN GA Res.47/68) [hereinafter the *1992 Principles*]

populated territories, it would have had serious consequences. States are aware of all the potentials presented by nuclear energy.

The utilization of NPS as weapons is the only existing violation defined under article IV of the Outer Space Treaty.[51] Article IV prohibits the "plac[ing] in orbit around the Earth [of] any objects carrying nuclear weapons or any other kinds of weapons of mass destruction." Besides this clause, neither authorization nor prohibition is to be found in the other international agreements.

While the lawfulness is not questioned, activities involving NPS are regulated and restricted.

The use of NPS in outer space is regulated: Prior to 1992, no international agreement directly and exclusively addressed the use of NPS in outer space. The issue was raised by Canada in 1978, after the COSMOS 954 incident.[52] Canada suggested a review of existing instruments and a possible elaboration of a new regulation either in the form of a treaty, through general principles, or through recommendations.

The item was put on the Agenda of the Scientific and Technical Subcommittee (STSC) and of the Legal Subcommittee (LSC) of the Committee on the Peaceful Uses of Outer Space (COPUOS), and Groups of Experts were constituted to study it. The *Principles Relevant to the Use of Nuclear Power Sources in Outer Space*

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51 *Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies*, opened for signature at London, Moscow and Washington on 22 April 27 January 1967, entered into force on 10 October 1967, 610 U.N.T.S.205;18 U.S.T. 2410 T.I.A.S. 6347; (1967) 6 I.L. 386 [hereinafter *Outer Space Treaty*].

52 *Supra* note 2.

were adopted in the form of a Resolution of the United Nations General Assembly,[53] which nevertheless does not confer the *Principles* a legal binding force.

In paragraph 4 of the Preamble of the *Principles*, Member States recognize:

> the need [...] for a set of principles containing goals and guidelines to ensure safe use of nuclear power sources in outer space..

The issue, temporarily concluded in 1992, was therefore not to authorize or forbid the use of NPS but to regulate such use.

<u>The use of NPS is restricted</u>: lawful and regulated, the use of NPS is also restricted (1) to missions which cannot be operated without using NPS for energy generation, (2) the start-up of energy generation using nuclear power is to take place out of the Earth's atmosphere and (3) the nature of the NPS is also restricted.

The use of NPS is limited to missions where no other energy source is available: If the UN, and the Member States with them, recognize the need for NPS on board spacecraft, their use is restricted only to cases where such need arises. It is the subject of paragraph 2 of the Preamble, and in a more precise manner of Principle 3. Paragraph 2 of the Preamble states that:

> the use of NPS in outer space should focus on those applications which take advantage of the particular properties of NPS.

The mentioned paragraph could stay a vague recommendation, but Principle 3 elaborates and restricts further the use of NPS "to those space missions which cannot be operated by non-nuclear energy sources in a reasonable way."

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53 *Supra* note 50.

Locations where the power source may be activated are limited: In this case a distinction is made between nuclear reactors and RTGs. Nuclear Reactors may be made critical when the spacecraft has reached (1) interplanetary orbits, (2) sufficiently high orbits and, (3) in low earth orbits provided that after completion of operations, the NPS be stored in a sufficiently high orbit.[54] RTGs may be operated (1) in interplanetary missions, (2) once they are out of the gravity field of the Earth and, (3) in an Earth orbit but if they are stored in a high orbit after completion of operations.[55]

The type of fuel used for nuclear reactors is restricted to highly enriched uranium 235.[56] No restriction is set forth for RTGs.

2. Applicability and Scope of International Law

The use of outer space is a universal right however not absolute as launches of spacecraft and missions planned have to be carried out in accordance with several principles of international law which form the initial basic legal framework for the use of NPS, and are drawn from the *Outer Space Treaty* as well as from other conventions, as enumerated below. The present section covers the conventions and their role in the overall control of the use of NPS while the main legal issues relating to the use of NPS are addressed under separate headings, in Sections B, C, and D below.

International law is applicable to the use of NPS in outer space. The *Outer Space Treaty* of 1967, and in particular article III, reaffirms the relevance of

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54 Principle 3, para.2(1).

55 *Ibid.* para.2(3).

56 *Ibid.*

international law and of the UN Charter, in the exploration and use of outer space, therefore applies to activities involving the use of NPS. Article III reads as follows:

> States Parties to the Treaty shall carry on activities in the exploration and use of outer space, including the Moon and other celestial bodies, in accordance with international law, including the Charter of the United Nations, in the interest of maintaining international peace and security and promoting international cooperation and understanding.

Specific reference to the applicability of international law and in particular of the UN Charter and the *Outer Space Treaty*, is reminded in Principle 1 of the *1992 Principles*.

- According to the Outer Space Treaty, space activities, using or not NPS, are to be conducted "for the benefit and in the interest of all countries"[57],"without discrimination...on a basis of equality",[58] "in accordance with international law",[59] and "in the interest of maintaining international peace and security and promoting international cooperation and understanding".[60] Additionally, the *Moon Agreement*[61] with regard to the Moon and other celestial bodies, states that missions are to be conducted "exclusively for peaceful purposes."[62]

- Another principle applicable to the use of NPS, as seen in Section A.1 above,

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57 *Outer Space Treaty, supra* note 51 article I(1).

58 *Ibid.* article I(2).

59 *Ibid.* article I(2) and III.

60 *Ibid.* article III.

61 *Agreement Governing the Activities of States on the Moon and Other Celestial Bodies*, opened for signature at New York on 18 December 1979, entered into force on 11 July 1984, 1363 U.N.T.S. 3; (1979) 18 I.L.M. 1434 [hereinafter *Moon Agreement*].

62 *Ibid.* article 3(1).

concerns the prohibition of placing nuclear weapons in space. It is important to note therefore, that nuclear generation has to fall within the "equipment or facility necessary for peaceful exploration of the Moon and other celestial bodies"[63] which "shall not be prohibited."[64] It is the ground for the legality of the use of nuclear generation on spacecraft, for example, for the planned Mars Base, which would serve as a launch base to explore other planets. As will be seen further down, the *Outer Space Treaty* addresses also issues such as **information** relating to the launch and mission with NPS on board, and the overall **responsibility** of States for activities carried out in outer space.

- The *Agreement on the Rescue of Astronauts, the Return of Astronauts and the Return of Objects Launched in Outer Space*[65] of 1968 deals with the **assistance** provided by Parties to this agreement in case of a potential risk to another State.

- The *Convention on International Liability for Damage Caused by Space Objects*[66] of 1972 deals also with **assistance** to States but more particularly with **liability and compensation** resulting from a damage to another State.

- Finally, the *Convention on Registration of Objects Launched into Outer Space*[67]

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63 *Ibid.* article 3(4).

64 *Ibid.*

65 *Agreement on the Rescue of Astronauts, the Return of Astronauts and the Return of Objects Launched into Outer Space*, opened for signature at London, Moscow and Washington on 22 April 1968, entered into force on 3 December 1968, 672 U.N.T.S. 119; 19 U.S.T. 7570, T.I.A.S. 6599, (1968) 7 I.L.M. 151 [hereinafter *Rescue Agreement*].

66 *Convention on International Liability for Damage caused by Space Objects*, opened for signature at London, Moscow and Washington on 29 March 1972, entered into force on 1 September 1972, 961 U.N.T.S. 187; 24 U.S.T. 2389, I.I.A.S. 7762 [hereinafter *Liability Convention*].

67 *Convention on Registration of Objects Launched into Outer Space*, adopted 14 January 1975, entered into force on 15 September 1976, 28:1 U.S.T. 695, T.I.A.S. 8480 (hereinafter (continued...)

also deals with **information** to be provided by States launching space objects.

3. Applicable Nuclear Energy Law

Energy law is separately addressed as the conventions that are mentioned below primarily address ground nuclear activities in general although their scope apply to space activities involving nuclear energy. The applicable nuclear energy law is to be found in two conventions signed under the aegis of the International Atomic Energy Agency (IAEA) in 1986, the *Convention on Early Notification of a Nuclear Accident*[68] and the *Convention on Assistance in Case of a Nuclear Accident or Radiological Emergency.*[69] The IAEA Conventions were developed after the Chernobyl accident. The Conventions apply to any accident involving facilities or activities under the jurisdiction of a State party to the convention, "wherever located", therefore their scope is larger than that of the space conventions. The Soviet delegation requested in 1987 that a comparative study be carried out in order to determine whether the *Principles* conform to the IAEA Conventions and recommendations.[70] However Canada opposed it, arguing that the Legal Subcommittee of COPUOS should better concentrate its efforts on the principles which were not yet agreed upon rather than reopen the discussions on matters already adopted. The study thus proposed remained undone although the Soviets

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[67](...continued)
Registration Convention].

[68] *Convention on Early Notification of a Nuclear Accident*, adopted 24-26 September 1986, opened for signature at Vienna and at New York, entered into force on 27 October 1986, IAEA OR, 1986, INFCIRC/335 [hereinafter the *Convention on Early Notification*].

[69] *Convention on Assistance in the Case of a Nuclear Accident* (1986), adopted 24-26 September 1986, opened for signature at Vienna and at New York, entered into force on 26 February 1987, IAEA, 1986, INFCIRC/336 and Add.8, IAEA OR (1993), INFCIRC/336.Add.8. [hereinafter the *Convention on Assistance*].

[70] *Report of the Legal Subcommittee on the Work of its 26th Session (16 March-3 April 1987)*, UN COPUOS, 1987, UN GAOR, UN Doc. A/AC.105/385 (1987), Annex I at para. 6.

have in several occasions restated its necessity.

- The *Convention on Early Notification* specifically refers to the use of NPS in outer space. Indeed, article 1 defines the scope of application of the Convention and states that it applies to "any accident involving facilities or activities of a State Party." These facilities and activities are enumerated in art. I.2, and include "any nuclear reactor wherever located" (art.2.1(a)) and the "use of radioisotopes for power generation in space objects" (art. I.2(f)). The scope of the Convention is broad as it covers accidents which have occurred or which are likely to occur. The *Convention on Assistance* comprises "radiological emergencies" therefore a mere probability suffices to make the Convention apply.

Both conventions aim at responding to emergency situations. The *Early Notification Convention* also offers, if need be, a technical assistance in the form of experts services and personnel training (art.2.6 and art.5). It also provides that Parties must cooperate with the Agency and among themselves to facilitate prompt assistance in the event of a nuclear accident or radiological emergency in order to minimize its consequences and to protect "life, property and the environment from the effects of radioactive releases". The affected country, according to art. 2.1, are given the right to request assistance. This provision however, does not legally force the responsible State to offer assistance to the victim State. Furthermore, the country may even refuse to render such assistance if it considers itself not to be in a position to provide it. It should be noted that art. 2.1 gives the States the possibility to request assistance "whether or not [the] accident or emergency originates within its territory, jurisdiction control." This provision therefore allows any State, including the one who is responsible for the accident, to call for assistance.[71] The *Principles* of 1992 have also developed a regime of assistance to States described in Section

[71] A. Terekhov, "The 1986 IAEA Conventions on Nuclear Accidents and the Consideration of the Use of NPS in Outer Space in the Legal Subcommittee of COPUOS" (1987) *30th Colloquium on the Law of Outer Space* at 407.

B(B.2) below.

4. International Standards on Radiological Protection (ICRP) and International Basic Safety Standards for Protection against Radiation and for the Safety of Radiation Sources (IAEA)

In order to provide a safety regime and prevent radiological hazards, measures, *Standards* dealing with radiological protection were adopted at an international level, although not through a convention or treaty, and are regularly reviewed to protect populations and the environment against both normal and accidental conditions of the use of nuclear power generation in terrestrial applications.

Such standards and recommended practices are voluntary rules adopted by States and apply when no other legal regime is defined. Although such rules have, most of the time, customary origin, they are however not "optional" although they may be modulated/modified through conventions. Thus, by virtue of the standards and recommended practices adopted through the IAEA, States comply also with these norms.[72]

The existing, internationally recognized basic standards relating to radiation protection are the recommendations set by the International Commission on Radiological Protection (ICRP) with which most States comply. The International Commission on Radiological Protection (ICRP) is a non-governmental independent specialized organization created in 1928, whose mandate is, among others, to provide recommendations on all aspects of radiation protection which countries will freely integrate in national legislation or that international organization use as basis for international conventions/recommendations. The Commission is composed of members chosen on the basis of their recognized competence in the fields of

72 N.Q. Dinh, P. Daillier & A. Pellet, *Droit International Public*, 4th ed. (Paris: L.G.D.J., 1992) at 991.

medical radiology, radiation protection, health physics and radiation biology.

The ICRP recommendations are further embodied by standards of international organizations of the UN system (e.g, IAEA, WHO, ILO, IMO, etc.) as well as through regional organizations (e.g, OECD, EURATOM). Most notably, the International Atomic Energy Agency's Basic Safety Standards developed by the IAEA. In 1987, the ICRP started a general review of its recommendations in order to introduce new scientific data and notably all the scientific elements highlighted by the Chernobyl accident which resulted in a considerable update of the general recommendations concerning exposure to radiation of 1977[73] in Publication 60.[74] The review focused on modifications of the basic system for the limitation of radiation levels, and in particular, on a reduction of the limits of those levels which were in force.

The International Atomic Energy Agency has included these Standards and Recommendations in the "International Basic Safety Standards for Protection against Radiation and for the Safety of Radiation Sources"[75] and other publications formulated for handling radioisotopes (RTGs), disposal of nuclear waste, transport of radioactive materials, radiation protection and monitoring of radioactivity.[76] The BSS include the following principles applying to the protection of workers and of the general public:

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73 Recommendations of the ICRP, *1 ICRP Publication no.26*, 1 Ann.ICRP no.1 (Oxford: Pergamon, 1977).

74 Recommendations of the ICRP, *ICRP Publication no.60*, 21 Ann.ICRP (Oxford: Pergamon, 1991) no.1-3 [hereinafter the 1990 ICRP Recommendations].

75 "International Basic Safety Standards for Protection Against Ionizing Radiation and for the Safety of Radiation Sources" (BSS) Safety Series 115 STI/DAT/2 (Vienna: IAEA, 1996).

76 See e.g., "Regulations for the Safe Transport of Radioactive Material Safety Standards" Series No. ST-1/Requirements STI/PUB/998 (Vienna: IAEA, 1996).

- **Justification of the practice**: This principle was introduced in 1971 in ICRP-26.[77] No practice involving exposure to radiation should be adopted unless it produces a benefit that outweighs the harm it causes or could cause. In cases where the risk is shared by populations which are not receiving any benefit, the ICRP recommends that "the total collective dose equivalent should be kept below that which would have applied had the cost benefit assessment been confined to the population that received the benefit."

- **Optimization of protection**: Radiation doses and risks should be kept as low as reasonably achievable economic and social factors being taken into account; constraints should be applied to dose or risk to prevent an unfair distribution of exposure or risk.

- **Limitation of individual risk:** Exposure of individuals should not exceed specified dose limits above which the dose or risk would be deemed unacceptable. The maximum dose for the public is of 5 mSv per year. Occupational exposures (workers such as miners) are limited to 20 mSv per year averaged over five years, a maximum of 100 mSv in five years, with an additional limit of 50 mSv in any one year. The previous annual limit was 50 mSv.[78]

Most States incorporated these standards in their national legislations. The ICRP standards have been included in Principle 3(3.1) of the *1992 Principles* and any modifications in the standards are planned to be introduced in the *Principles*,

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77 *Supra* note 73.

78 The biological effect of radiation is expressed in Sieverts (Sv) or milliSieverts (mSv). This effect, "the dose equivalent", is calculated from the absorbed dose, after a correction is applied which takes into account the type of radiation and its location in the body.

however a specific procedure for the introduction of new standards is not described in the *Principles* (see *infra* Part III(C)).

The guidelines imply that the launching authority ensures that all precautions are taken during all the different phases of the mission, from the launch to the completion of the operation, to maintain an adequate radiation protection.

5. Customary Law establishing the responsibility for damages to the Environment

Customary law also applies to activities in outer space and several principles apply, in particular those relating to responsibility for damages caused to the environment.

International responsibility for damages caused to the environment has been established and the link between the two is based on the roman principle *sic utere tuo ut alienum non laedas* (use your property so as not to injure your neighbor).[79] This principle has been restated in the *Corfu Channel case* where the International Court of Justice held that it is "every State's obligation not to allow knowingly its territory to be used for acts contrary to the rights of other States."[80] This jurisprudence is limited to cases where the damage and the cause of the damage both occurred in the territory of the State responsible for that act. The duty is extended by the *Trail Smelter Arbitration,* to the territory of States other than the one in which the act causing the damage originates. In this case, the Arbitration Tribunal ruled that "no State has the right to use or permit the use of its territory in such a manner as to cause injury by fumes in or to the territory of another.."[81]

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79 H. Baker, "Space Debris: Legal and Political Implications" (1989) *32d Colloquium on the Law of Outer Space* 59 at 72.

80 *Corfu Channel Case* (United Kingdom v. Albania), (1949) 43 A.J.I.L. 558.

81 *Trail Smelter Arbitration*, (U.S. v. Canada), (1941) 3 UN Rep.Int. Arb. Awards 1905.

Another legal basis for international responsibility would be art.2(4) of the UN Charter. Environmental pollution could be presented in terms of violation of national sovereignty by foreign States. In the *Nuclear Tests case*, Judge de Castro (of a dissenting opinion) stated that:

> The applicant's [Australia] complaint against France of violation of its sovereignty by introducing harmful matter into its territory without its permission is based on a legal interest which has been well known since the time of Roman Law. The prohibition of *immissio* (of water, smoke fragments of stone) into the neighboring property was a feature of Roman Law. The principle *sic utere tuo ut alienum non laeda* [one must not use one's own property in such a way that injures another's] is a feature of law both ancient and modern. It is well known that the owner of a property is liable for intolerable smoke or smells, "because he oversteps [the physical limits of his property], because there is *immissio* over the neighboring properties, because he causes injury".[82]

The *Corfu Channel case* and the *Trail Smelter Arbitration* concern sovereign territories, under national jurisdiction. The scope of international responsibility was expanded further by Principle 21 of the 1972 *Stockholm Declaration on the Human Environment*[83] which states that States bear the responsibility "to ensure that activities within their jurisdiction or control do not cause damage to the environment of other States or of *areas beyond the limits of national jurisdiction.*" Principle 21 is part of customary law and States are responsible for ascertaining that their activities do not cause damage to the environment of other States or to places under no national jurisdiction including outer space. The recognition of international responsibility of countries entitles the affected State to claim for compensation as

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82 ***Nuclear Tests (Australia v. France)***, **[1974] I.C.J. 372 at 388.**

83 ***Declaration on the Human Environment***, **adopted by the United Conference on the Human Environment, Stockholm, 16 June 1972 [hereinafter *Stockholm Declaration*].**

ruled by the *Chorzów Factory case:*[84]

> [t]he essential principle contained in the actual notion of an illegal act...is that reparation must, as far as possible, wipe out all the consequences of the illegal act and reestablish the situation which would in all probability, have existed if that act had not been committed.

This decision therefore provides for a *restitutio in integrum* in favor of the affected State.

6. The 1992 *Principles*

6.1 Background to the adoption of the 1992 *Principles*

As mentioned earlier, the *Principles Relevant to the Use of Nuclear Power Sources in Outer Space* were adopted in 1992 after 13 years of negotiations within the UNCOPUOS. In 1978, Barton[85] proposed a review of the existing international instruments, implying that the previous ones, along with an empirical way of establishing new instruments were not sufficient for effective prevention of radiological contamination due to nuclear-powered spacecraft. The international community was, according to him, in the need of a specific instrument, which might become a Convention at a later stage, regulating and controlling strictly the use of NPS in outer space. This was done through the two Subcommittees of the COPUOS. The adoption of the *Principles* proved that for the first time, countries recognized the necessity to regulate the use of NPS in outer space with specific international guidelines directly addressing the problem, in a similar way as they had recognized the necessity to regulate the use of nuclear power for terrestrial

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84 *Chorzów Factory case*, (Germany v. Poland), [1928] at P.C.I.J. Ser.A, no.17 at 47-48.

85 Barton, *supra* note 2.

applications.[86]

Political motivations were not absent of the negotiations, in particular as far as the main space powers were concerned. Both the former USSR and the USA were pursuing different objectives relevant both to their internal and external policies. The trend of international relations regarding space law showed that the international consensus that existed in its first developments had come to an end, implying greater difficulties in the elaboration of new rules. The motivations of the US concerning the whole project of the *Principles* and more particularly with respect to its core point, i.e., Principle 3, may be traced through its political implications. In 1978, at the beginning of the negotiations, the USA presented a Working Paper[87] on their practice relevant to the use of nuclear power sources in outer space. This contrasted with that of the former Soviet Union which was reluctant to reveal anything relating to its activities in outer space.

During President Reagan's mandate the US tended to adopt a less open position, but the Soviets continued to be pointed at by the Canadians as those preventing the international community and its institutions to come to an acceptable solution. The new policy of M. Gorbachev put an end to the previous extreme reluctancy to cooperate in the elaboration of a set of rules on nuclear power sources in space. The difficult consensus on the Principle on Notification of Re-entry tended to show that the USSR had partially ceased to obstruct systematically the process of elaboration. On the contrary, as stated by Fauteux[88], the modifications in the US attitude was due not only to considerations of foreign policy but also to internal circumstances. Indeed, environmentalists and ecological groups started to grow

86 Barton, *Ibid.*

87 UN COPUOS, "USA practices relevant to the use of nuclear power sources in outer space", Working Paper submitted by the USA, 1978, UN GAOR UN Doc. A/AC.105/L.102.

88 Terekhov, *supra* note 71 at 19.

more powerful within the US at that time and the government was not inclined to provide international legal basis for their claims. This may explain their opposition to a principle on notification of the presence of NPS on board a space object, especially a notification before the launching of the object.

The position adopted by the USA also threatened the consensus decision-making in force within the COPUOS. The use of this method has been successful in bringing about international treaties relevant to the international space cooperation (1967 *Treaty on outer Space*, the 1968 *Rescue Agreement*, 1972 and 1975 *Liability and Registration Conventions*). Consensus is a non-voting procedure, parting from unanimous voting as it is achieved without voting, depriving States of what they tended to consider as a right of veto.[89] An analysis of the reasons of success of this method by E. Galloway showed that most States were willing to develop the then new activities and put aside their rivalries in order to do so. However, if on the one hand this method facilitates the implementation of the decisions adopted thereof, one of the most important drawback is the time involved to reach consensus. In the event some States misuse it as a right of veto, the General Assembly and its voting procedure is the sole solution available.[90] With respect to the adoption of the draft *Principles* on the Use of Nuclear Power Sources, the consensus was long to reach[91] and was broken in several occasions.

6.2 Scope and Revision of the *Principles*

The *Principles* only address NPS as electricity generation and not NPS as

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89 E. Galloway, "Consensus Decisionmaking by the United Nations Committee on the Peaceful Uses of Outer Space." (1979) 7 J.Space L. at 3.

90 See the adoption of the *Principles of Direct Broadcasting by Satellites* and P. Fauteux, "Radiodiffusion directe par satellite: adieu au consensus?", (1981) VI A.A.S.L. 345 at 373-379.

91 Galloway, *supra* note 89.

propulsion systems, however, Principle 11 provides for the revision of the *Principles* "no later than two years after the adoption of the *Principles*" which seemed promising and positive and indicative of the UN intention to keep up with the technological innovations and keep the *Principles* up-to-date with the changes. However, in 1997, although the revision of NPS was still an item of the agenda of the Legal and Technical Subcommittees and of the COPUOS, the latter agreed that ".. a revision of the *Principles* was not necessary at the current stage.."[92] and that:

> Regular discussions on the issue should continue at future sessions of the Scientific and Technical Subcommittee and [that] the Subcommittee and the Working Group should continue to receive the widest input on matters affecting the use of nuclear power sources in outer space and new contribution related to improving the scope and application of the *Principles*.[93]

The Legal Subcommittee also decided that, for 1998 (36th session):

> consideration by the Working Group on agenda item 3 of the *Principles* relevant to the Use of Nuclear Power Sources in Outer Space should again be suspended for one year, pending the results of the work of the Scientific and Technical Subcommittee...[94]

While the issues which would be subject of revision will be discussed in details later (See *infra* Part III), it should be kept in mind that the primary goal of the *Principles* was to set up a general framework in which activities involving NPS could take place in as safe a manner as possible by providing guidelines. The main goal of a revision, if it ever occurs, "must be aimed at strengthening the guidelines

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[92] UN COPUOS, ***Report of the Committee on the Peaceful Uses of Outer Space on the Work of its 52d Session***, **UN GAOR, 1997, Supp. 20, UN Doc. A/AC/20, at para.79.**

[93] ***Ibid.*** **at para. 80.**

[94] ***Ibid.*** **at para. 25.**

through which NPS systems may be utilized safely and effectively."[95]

The *Principles* refer to two elements (1) the types of power sources and (2) the "area" concerned.

* **Type of Power sources**: The *Principles* so far apply to power sources only used for electric generation and do not cover what represents more than a potential i.e., nuclear power sources used for propulsion purposes (for now only designed for interplanetary flights). The Preamble of the *Principles* also "recognizes that for some missions in outer space nuclear power sources are particularly suited or even essential due to their compactness, long life and other attributes". The use is therefore not forbidden but on the contrary recognized as necessary due to technical capacities of nuclear power which simply cannot be replaced by other sources of power generation (See *supra*, Part I).

* **Area concerned**: is the **"entire" Outer Space**, and thus encompasses Low Earth Orbit (LEO) where most space activities take place, and all celestial bodies in particular the Moon and Mars where future human activities are the most probable. However, it is from activities taking place close to the Earth's atmosphere that the existence and application of the *Principles* draw all their importance.

B. Areas Regulated by International Instruments

The present section studies the concrete measures taken to regulate the activities involving the use of NPS in outer space. The measures are of three categories (1)

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95 N. Jasentuliyana, ed., *Perspectives on International Law*, (London: Kluwer Law International: 1995), at 373.

preventive measures, so as to avoid or minimize the risks attached to the use of NPS, (2)emergency measures aiming at minimizing the consequences of an incident or accident of a space object with NPS on board and finally (3) measures dealing with the reparation of such events, mainly the liability and compensation regime.

B.1 Preventive Measures

1. Safe Use

The adoption of the *Guidelines and Criteria for Safe Use* was difficult. During the negotiations of the *Principles* and in particular of Principle 3 it was argued that the adoption of this particular Principle would both make the use of nuclear power sources in outer space safer and perceived as such by the population.[96] The content of Principle 3 was agreed upon in 1990.[97]

The first preventive measures set up by the *1992 Principles* provide general guidelines, a framework of rules for the design of space objects with nuclear power sources on board. This Principle is based on the recognition that if it is impossible to eliminate the risks relevant to the use of nuclear power sources altogether, it is possible to try and limit such risks. The criteria are set forth in Principle 3 and contain "recommendations" pertaining to (1) who/what the guidelines aim at protecting, (2) the guidelines concerning the general design of space objects containing NPS and (3) guidelines pertaining directly to the nuclear source used.

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96 UN COPUOS, ***Report of the Legal Subcommittee on the Work of its 27th Session on the Elaboration of Draft Principles Relevant to the Use of NPS in Outer Space***", **Declaration of the Canadian Ambassador de Montigny Marchand, Head of the Canadian Delegation.**

97 UN COPUOS, ***Report of the Legal Subcommittee on the Work of its 29th Session,*** **1990, Annex I, UN GAOR UN Doc. A/AC.105/457 (1990) at par.12.**

The *Principles*, hence the guidelines embodied in Principle 3, aim at protecting "individuals, populations and the biosphere" (Principle 3(1). The last paragraph also cites outer space, which has to be protected from radiation contamination.

Regarding individuals and populations, the fact that individuals and populations are separately cited shows Member States' interest in protecting also the individual against radiation exposure. It should be noted in this context that during the period before the launching of Cassini with NPS on board (plutonium 238- more than 30 kg, the largest amount ever launched in space so far), groups of anti-nuclear "activists" fought to obtain cancellation of the launch and argued that NASA had not properly assessed the number of humans which might be affected by a potential accident. NASA's estimates varied between 120 and 2,000 potential deaths while the main group orchestrating the campaign against Cassini, the Florida Coalition for Peace and Security presented an estimate of more than 200,000.[98] NASA issued many press releases and documents, most notably the Cassini Final Environmental Impact (even posted on the Internet) to convince people in general that the risks were minimal. The economic cost most certainly enters into account although such element is not present in any of the 1992 *Principles*. Such element clearly appears in the decision of a Judge of a US District Court who ruled that "the economic and scientific harm that NASA and other defendants in the case would suffer if the launch [of Cassini] were delayed outweighed the potential harm asserted by the two groups."

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98 W.J. Broad, "Powered by Plutonium, Saturn Mission Provokes Warnings of Danger" *New-York Times* (8 September 1997).

2. Guidelines on Design

In design and use, measures against "foreseeable operational and accidental circumstances" are to be integrated (Principle 3(1.1): The main point of discussion in this case is on the term "foreseeable". Principle 3(2) refers to Principle 2 on Definition of terms and in particular to paragraph 3, where "foreseeable" is meant so as to encompass only "credible possibilities" of malfunction, i.e., events which are known to have occurred or are likely to occur. It is possible that such definition will be useful in particular for responsibility purposes, to establish a case of responsibility while, at the same time, setting a limit to such responsibility as it would be only actionable if designers had failed to integrate measures against events known of likely to occur.

Safety systems must be designed so as to abide by the "defence-in-depth concept"(Principle 3(1.4): the concept of **"defence-in-depth"** is defined in Principle 2.3, and means that safety systems have to be installed or any other measure planned to prevent, mitigate, counteract the failure of the first safety system. The definition specifies that such term does not necessarily mean that all safety systems must be made redundant but at least other measures must exist. In short, defence-in-depth is a multilayer system of protection and safety provisions commensurate with the radiation hazards involved is applied to sources, so that a failure at one layer is compensated for or corrected by subsequent layers.

The radiation exposure tolerated is limited: to 1mSv/year. Such limit is set in Principle 3(1.3) and is to be taken into account in the design and operation (including re-entry) of space objects with nuclear power sources on board. The limit mentioned is more stringent than for terrestrial applications (see *supra* Part I(A.4). As mentioned earlier, this Principle had received agreement from all States in 1990 but in 1991, the United States presented an official proposal of amendment before the LSC,[99] whereby they requested that the radiation exposure, restricted in the 1990 agreement to "a limited geographical region and to individuals to the principal limit of 1mSv in a year" be replaced by the more general "risks as low as reasonably achievable". Two explanations regarding this attitude have been envisaged.[100] The US presented their amendments as resulting from new data obtained through the Space missions Ulysses and Galileo. These amendments were probably meant to adapt Principle 3 to the national regulations, modified after these missions. However, one could seek an explanation in the then-new project the US had of developing a nuclear powered rocket, Timberwind.[101] Principle 3 has been conceived to apply to NPS used as sources of electricity. The SDI project used a reactor to produce heat and not electricity. The principle on guidelines and criteria for safe use would therefore need a substantial revision in order to apply to direct nuclear propulsion. However, it seems that instead of a revision the USA excluded the nuclear thermal propulsion from the scope of the UN *Principles* on the basis that it uses a reactor to produce heat and not electricity.[102] Nevertheless, as noted by P. Fauteux,[103] Timberwind had to overcome various technical and financial problems thus, there was no real need for the US to reopen the discussion on that particular matter at this particular time. The 1 mSv limit for one year therefore remained valid (Principle 3(1.3). Any modification of the former will be introduced in the *1992 Principles* as provided by Principle 3(1.3), however no specific procedure to do so is planned by the *Principles*.

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99 UN COPUOS, USA Proposal of Amendment presented before the Legal Subcommittee, UN GAOR, 1991, UN Doc. A/AC.105/C.2/L.185.

100 Terekhov, *supra* note 71 at 407.

101 Timberwind, *supra* note 49.

102 S. Aftergood, "Space nuclear Power and the UN-a growing fiasco" *Space Policy* (February 1992) 9 at 12.

103 Terekhov, *supra* note 71.

3. Safety Assessment

As part of the preventive measures set up by the 1992 *Principles*, the conduct, prior to the launch, of a Safety Assessment of the object, of its components and of the NPS therein was established as well as communication of the results, also prior to the launch, to the United Nations Secretary-General (See point 4. below).

First of all, it should be noted that Member States did not try to minimize the potential risks entailed by the use of nuclear power sources, and **recognized** in paragraph 4 of the Preamble of the *Principles*, the **existence of a risk of** contamination and radiation hazards attached to the use of nuclear power:

> [...] the use of NPS in outer space should be based on a thorough safety assessment, including probabilistic risk analysis, with particular emphasis on reducing the risk of accidental exposure of the public to harmful radiation or radioactive material.

The Safety Assessment is the Technical evaluation of all elements of the space object, the nuclear power source and the launch installations. It "covers [..] all relevant phases of the mission" and "shall deal with all systems involved, including the means of launching, the space platform, the nuclear power source and its equipment and the means of control and communication between ground and space." (Principle 4(1).

The purpose of the Safety Assessment is to reduce the existing and potential risks attached to launching nuclear power reactors or RTGs in outer space by ensuring that all guidelines (as outlined below in the criteria for safe use) were followed by designers and manufacturers and that up-to-date technology and knowledge were applied to all the phases of designing and manufacturing of the space object, the launching facility and the nuclear source of energy.

Conduct of the Safety Assessment: the "launching State" of Principle 4 as defined in Principle 2(1),i.e.:

> the State which **exercises jurisdiction and control** over a space object with NPS on board at a given point in time relevant to the principle concerned.

The solution to a serie of objections (see *infra* Part III (B)) was a compromise:

> A launching State as defined in principle 2, paragraph 1, at the time of launch, shall, prior to the launch, through cooperative arrangements, where relevant, with those which have designed, constructed, or manufactured the nuclear power source, or will operate the space object, or from whose territory or facility an object will be launched, ensure that a through and comprehensive safety assessment is conducted.

Therefore, the responsibility or carrying out the Safety Assessment is vested upon:

- The launching State as per definition of Principle 2(1) or the State ordering the launch;
- All agencies/firms involved in the designing, manufacturing and construction of the nuclear power source;
- The operator of the object;
- The State providing the launching facility.

Such measure implies a large cooperation between all those involved, including possibly private companies and all States participating to the venture, therefore covering the possible future space stations, Mars and Moon bases, where not only one space agency of one single country will be involved. Agreements will need to be negotiated to define each one's responsibility in the conduct of the Safety Assessment.

The definition of the "launching State" also posed a problem regarding the notification of launch of objects carrying nuclear power sources.

4. Notification of Launch to Secretary-General of the United Nations

The publication of information pertaining to the launch and mission of satellites with NPS on board is an important issue to control the use of nuclear power sources in outer space. Prior to 1992, customary law had established the norm that:

> [a] State is under a duty to notify any other State which may be threatened by harm from the abnormally dangerous activities which the State permits to be conducted within its jurisdiction.[104]

applicable provisions were set forth in the *Outer Space Treaty* as well as in the *Registration Convention* applicable to any launch.

- **Article XI of the 1967** Treaty requires that State Parties agree to inform the United Nations Secretary-General, the Public and the Scientific Community of the "nature, conduct, location and results of such activities."

- **Article IX of the *Registration Convention*** states that Parties "shall furnish to the Secretary-General of the UN" a certain number of information listed in the article, such as, for instance, the name of the State of Registry, basic orbital parameters and, the general function of the space object."

The problem lies in the fact that **information was not a mandatory procedure**. The 1967 Treaty specifies that such information is provided "to the greatest extend feasible and practicable" whereas the 1975 Convention states that it is done "as soon as practicable". Moreover, complement of information may be provided but on

[104] *Corfu Channel Case, supra* note 80.

a voluntary basis, according to article IV(2) of the *Outer Space Treaty*, where States may furnish the Secretary-General "with additional information."

- Furthermore **Article 7(2) of the *Moon Agreement*** of 1979 requires that States give the Secretary-General advance notice of "the placement ...of radioactive materials on the Moon and on the purposes of such placement." However, this Agreement is not ratified by the major space States and, *a fortiori* by the USA and the former Soviet Union, thus implying that such a measure has little chance to be given any enforcement by States.

With respect to notification to the Secretary-General, the above mentioned provisions were the sole obligations borne by countries by international law. In 1978 Resolution 33/16 was adopted by the General Assembly, and created the obligation for the launching State to inform States concerned in the event of a malfunctioning nuclear-powered satellite presenting risks of re-entry of radioactive materials.[105] Such obligations were not reinforced by the *1992 Principles*. Indeed, the notification to the UN Secretary-General does not exist *per se* in the *Principles*, as a separate article. Disagreement on this point during the negotiations of the *Principles* led to the adoption of a compromise embodied in Principle 4 titled *Safety Assessment*.[106]

The communication of the results of the Safety Assessment (see *supra* point 3) acquires the value of a registration of a nuclear power source. Principle 4, para. 3 requires that:

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[105] **Resolution 33/16 adopted 10 November 1978 added, among others, to the agenda of the Scientific and Technical Subcommittee the use of NPS in outer space.**

[106] **M. Benkö, G. Grüber and K-U. Schrogl, "The United Nations Committee on the Peaceful Uses of Outer Space: Adoption of the Principles relevant to the use of Nuclear Power Sources in Outer Space" (1993) *36th Colloquium on the Law of Outer Space* 231 at 236-237.**

> The result of th[is]e Safety Assessment, together with, to the extent feasible, an indication of the approximate intended time frame of the launch, shall be made publicly available prior to each launch, and the Secretary-General of the United Nations shall be informed on how States may obtain such results of the safety assessment as soon as possible prior to each launch.

Points of disagreement covered the type of information to provide and who the provider would be.

The information to be provided is the results of the Safety Assessment to the UN Secretary-General and not the Safety Assessment in its entirety, in order to avoid unfeasible communication of large pieces of documentation as well as the disclosure of confidential, military or scientific data.

The launching State referred to in Principle 4: is the State as defined in Principle 2(1),i.e., it raised the same problem as it did for the Safety Assessment (see *infra* Part III (B.1).

The compromise found is that the providers of the information are those who conducted the Safety Assessment, i.e., the "launching State as defined in Principle 2 [...], those who designed, constructed, or manufactured the nuclear power source, or will operate the State object, or from whose territory or facility such an object will be launched..." This will be arranged through cooperative arrangements prior to the launch. For the launch of Cassini, the US addressed a *Note Verbale* to the Secretary-General in June 1997, whereby the US indicate that "a thorough assessment and an extensive safety analysis for the Cassini mission" has been conducted and that "the results of the safety assessment are publicly available and can be obtained.." from NASA.[107] Similarly, although in a less transparent manner,

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107 *Note Verbale dated June 1997 from the Permanent Mission of the United States of America to the UN (Vienna) addressed to the Secretary-General*, UN COPUOS, 1997 UN GAOR, UN (continued...)

the Russian Federation also addressed a *Note Verbale* informing the Secretary-General of the launching on 16 November 1996 of the Russian space vehicle Mars-96, carrying radionuclide heat sources based on plutonium-238, adding that the heat sources "are leak-proof and reliable to a high degree and meet the special international and national requirements for radiation safety."[108] Both Notifications did not present much problems as clearly both countries were the launching States and did not involve others in the design or the launching of the objects.

B.2. Emergency Measures: Notifications and Assistance

1. Notifications of Malfunctioning

The section covers not only the notification of re-entry addressed by the *1992 Principles* but also the more general notification of a potential or existing release of radiological materials, subject of the *Convention on the Early Notification* of a Nuclear Accident.

1.1 Notification of re-entry

Such event is covered by the *1992 Principles*, in **Principle 5**:

> Any State launching a space object with nuclear power sources on board shall timely inform States concerned in the event this space object is malfunctioning with the risk of re-entry of radioactive materials to the Earth.

The rest of Principle 5 (see *infra*) concerns the elements of information to be

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[107](...continued)
Doc A/AC.105/677.

[108] *Note Verbale dated 15 November 1996 from the Permanent Mission of the Russian Federation addressed to the Secretary-General*, UN COPUOS, 1996, UN GAOR UN Doc. A/AC.105/647.

provided.

Principle 5 is a step forward compared to the earlier measures that existed, as finally, in a document directly relating to space activities, the "obligation" of information is finally introduced. This is a recognition of the potential severe consequences that retention of information might have for all countries, in case of malfunctioning and subsequent re-entry of a space object with nuclear power sources. The benefit of such requirement is therefore general.

The State responsible for providing the information is the "launching State" as defined in Principle 2, i.e., one exercising jurisdiction and control over the object at the moment when the malfunctioning and risk of re-entry is known.

- **The information is provided to all States that may be affected**. As far as updates of information provided are concerned (see below) the information is to be provided to the Secretary-General so as to allow access to all States willing to obtain the information.

- **The information is to be provided in a "timely manner" when malfunctioning is known** (Principle 5, 2): such time requirement is vague and is part of the many terms of the *Principles* which weaken their value.[109] "Frequent" updates are also required in order to follow exactly what is happening and are required to increase in frequency as soon as re-entry and possible impact are approaching.

- **Type of Information:** this element is twofold:
  - The <u>system parameters</u>: that is, all information about the flight in

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109 **C.Q. Christol, "Nuclear Power Sources (NPS) for Space Objects: a New Challenge for International Law" (1993) *36th Colloquium on the Law of Outer Space* 244 at 246.**

order to better predict (if possible and feasible) the "orbit lifetime, trajectory and impact prediction" (Principle 5(A).

- Radiological Risks of NPS, that is the type of nuclear sources used, the physical form, essential to try and determine possible points of impacts and velocity, and the amount and characteristics of "fuel", i.e., of nuclear sources (Principle 5(B2).

As mentioned earlier (*supra* Part I), the Russian Federation launched the Mars-96 mission which failed immediately after launching: the ignition of the booster rocket which was to propulse the space object into a flight trajectory towards Mars did not function and the booster, the rocket and the object remained in Earth orbit. The Federation issued a second *Note Verbale* on 18 November 1996 "informing the Secretary-General of the incident, and of the re-entry of the space object [in] the dense layers of the Earth's atmosphere."[110] The Secretary-General was further informed that the object "having disintegrated, ceased to exist, falling into the waters of the Pacific Ocean...in the area of eastern Australia."[111] Finally, the Secretary-General was assured that "the radionuclide energy sources based on plutonium-238 which were on board [...] w[ould] not disintegrate in any foreseen circumstances."[112]

In 1983, the debate on NPS in the Legal Subcommittee was based on the

110 *Note Verbale dated 18 November 1996 from the Permanent Mission of the Russian Federation addressed to the Secretary-General*, UN COPUOS, 1996, UN GAOR UN Doc. A/AC.105/648.

111 *Ibid.*

112 *Ibid.*

COSMOS 1402 incident[113] and on a Working Paper submitted by Germany.[114] The consensus reached on this Principle was an important step towards a modification of international law with respect to the use of NPS in Space.[115]

1.2 Notification of a radioactive release or of a risk

The *Early Notification Convention* of 1986 mentioned earlier (see *supra* Section A(3), also places under its scope "any reactor wherever located"(art.1.2(a) and "the use of radioisotopes for power generation in space objects" (art. 1.2(f). The Convention contains a set of measures concerning the notification to other States in the event a "release of radioactive materials occurs or is likely to occur and which has resulted or may result in an international transboundary release" which could have radiological effects on the concerned countries.

Article 2 of the Convention imposes on the launching State to notify directly or through the Atomic Energy Agency, the States which might be concerned by the release or potential hazard of the "nuclear accident, its nature, the time of its occurrence and its exact location."(article 2(a).

The information to be provided in the notification is defined first, so as to encompass "such available information relevant to minimizing the radiological consequences" in the concerned countries (art. 2(b) and developed in article 5 so as to cover all technical parameters of the object responsible for the release, the environmental conditions, location of the event and the monitoring of the situation

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113 "COSMOS 1402 fell in the Indian Ocean" *The [Toronto] Globe and Mail* (24 January 1983) 1.

114 P. Fauteux, "Sources d'Energie Nucléaire dans l'Espace; Bilan Réglementaire et Incertitudes Américaines" A.A.S.L. 1991 at 267.

115 M. Benkö, W. de Graaf, G.C.M Reijnen *et al.* "Space Law in the United Nations" (Dordrecht, Neth.:Martinus Nijhoff, 1985).

and communication of regular updates on the situation. While art.5 defines the type of information that must be provided, another provision requires that any request for further information or consultation be responded to promptly by the notifying State Party (article 6).

As mentioned above, the *Convention on Early Notification* and the *Principles* somewhat duplicate the measures to be taken in the event of an "accident", "re-entry" and "release of radioactive materials." In the event of a release "the Convention will apply to all accidents causing a cross-border nuclear pollution."[116] As mentioned above, the Convention covers all accidents involving nuclear power sources, whether in space or on the ground (see *supra*, Section A(3). Again, the extent of the application of the Convention is still problematic as it speaks about "nuclear accidents" and the term "accident" is not yet precisely defined. More conveniently, Principle 5 refers to "malfunctioning" object, therefore it applies prior to the occurrence of any release, in case a space object threatens to re-enter the atmosphere. The notification requirements therefore applies at an earlier stage than in the Convention and allows the tracking and the set up of preventive measures to start earlier. In the event of actual re-entry, both legal instruments apply as "in such case an accident could be assumed."[117]

Principle 5 is more "protective" than the Convention since:

- The Principle does not require the existence of an event of "radiological safety significance" for the victim State, the mere risk of re-entry of NPS or components thereof, triggers the notification procedures;
- There are no conditions of a potential or existing "transboundary

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116 M. Benkö & J. Gebhard, "International Space Law in the Making" (1993) at 64.

117 Benkö & Gebhard, *supra* note 116.

release of radioactive materials" as such transboundary element would be difficult to establish for a space object coming directly from space, with no border between the affected State and the "launching State."

Finally, it should be noted concerning the question of duplication that the *Convention on Early Notification* expressly states in article 10 that in case of duplication between the provisions of the Convention and other existing legal instruments or future agreements, the reciprocal rights and obligations of State Parties which relate to the matters covered are not affected.

2. Assistance to States

The issue of Assistance to States is hereby separated in 2 subsections. The first one addresses the applicable dispositions at the time of the Cosmos 954 accident, whereas the second concentrates on the requirements set forth by the *1992 Principles*.

2.1 Applicable dispositions prior to 1992

The issue of Assistance was covered by Article 5 of the 1968 *Rescue Agreement* and, by article XXI of the *Liability Convention*, the burden of offering assistance was placed on the launching State although the victim State was not obliged to accept it or even request it.

Art.5.4 of the *Rescue Agreement* requires "a Contracting party which has reason to believe that a space object... discovered... or recovered by it..., is of a hazardous or deleterious nature may so notify the launching authority, which shall immediately take effective steps, under the direction and control of the said Contracting Party, to eliminate possible danger or harm." Furthermore, Art. XXI of the *Liability Convention* adds that "the States Parties and, in particular the launching State, shall examine the possibility of rendering appropriate and rapid assistance to the State which has suffered the damage, when it so requests..."

From these two provisions the victim State is by no means obliged to request assistance from the launching country and may therefore require it from any other Party. This issue was one of the problems opposing the USSR and Canada where the point of the argument was to establish who, in any case, would be responsible for the costs incurred by the search of the radioactive debris. The Soviet Union founded its argument on article 5.4 of the *Rescue Agreement*, and on the fact that, in their view, the launching State is the only one mastering all the specific characteristics of the object and of the NPS on board, therefore recovery and handling of the remains could be done in a faster, more efficient and less costly manner[118] than by any other States. On the other hand, Canada along with other States, asserted the choice of the State to render assistance to be a sovereign right of the victim State, although State responsible for the damage should reimburse the costs of the search even if its assistance was not requested for the search.

2.2 Principle 7 - Assistance to States

Principle 7 of the *1992 Principles* establishes obligations of assistance on all states as well as on the launching State.

a) Obligations vested on all States

Prior to re-entry all States are to use their tracking facilities to locate the

118 Q. He, "Towards a New Legal Regime for the Use of Nuclear Power Sources in Outer Space" (1986) 14 J.Space L., 95 at 96.

malfunctioning space object with NPS on board. The measure applies as soon as a notification of expected re-entry has been issued. Such measure is intended as a precautionary measure to find the object as soon as possible and it is to be done "in the spirit of international cooperation" (Principle 7(1). Information obtained are to be communicated to the United Nations Secretary-General and to the States concerned.

After re-entry, State parties with relevant technical capabilities and upon request of the affected State are requested to render assistance to State(s). Such measure also applies to international organizations which also have such technical capabilities (Principle 7.2(b).

b) Obligations vested on the Launching State

- Assistance must be offered by the launching State and must be rendered by the launching State to the affected State if the latter so requires:

After re-entry, the launching State (as defined in Principle 2(1), i.e., the State exercising jurisdiction and control over the object) has the obligation to offer its assistance to the affected State(s) (Principle 7.2(a). However, the affected State does not have to request assistance from the launching State as Principle 7.2(a) stipulates "the launching State shall promptly offer, **and if requested by the affected State**".

Most States possess neither monitoring and tracking facilities, nor technology, equipment, personnel or financial means necessary to face the re-entry of nuclear-powered objects. This issue, highlighted in 1978, as COSMOS 954 operated its re-entry, became one of the principal concerns of developing countries. From a legal point of view, the focus had to be put on to whom the affected State was to require assistance. The existing conventional provisions applicable to that matter were rather imprecise. Articles 5(4) of the *Rescue Agreement*, provides that a Contracting Party which discovers or retrieves a space object which is believed to be of a hazardous or deleterious nature "may" so notify the launching authority which shall take effective steps so as to eliminate the risk. Furthermore, article XXI of the *Liability Convention* indicates that in the event of a large-scale danger, "the States Parties, and in particular the launching State" are to "examine the possibility of rendering assistance" to the affected State. During the discussions in the Legal Subcommittee, the Soviet Union pretended initially to create a preferential right to render assistance in favor of the launching State. It based its demand on the fact that the launching State, being fully informed about the technical aspects of the object, is the sole Party able to render both an efficient and cost-effective assistance. This referred to the 1978 incident where Canada had declined the offer of the Soviets in favor of that of the Americans. Nevertheless, the majority point of view prevailed in the consensus met in 1986[119] which entailed that the victim State has the choice to call for assistance from any State. This decision was principally based on the fact that such a choice pertains to States' sovereign right as well as on the above mentioned art. XXI which, explicitly contains this possibility. In conclusion, the equipped States, "in the spirit of international cooperation", are to communicate information they may have on the concerned nuclear-powered object, to the Secretary-General and the affected State. Furthermore, the launching country is to provide a prompt assistance in view of eliminating the harmful effects.[120] It is also responsible for all the costs involved for the search, recovery and clean-up of the remains but, this issue is addressed in a different principle (see *infra*, Section B3(2).

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119 *Assistance to States*, COPUOS Legal Subcommittee, *24th Sess.*, Annex II, UN Doc. A/AC.105/352 (1985) para.7.

120 Principle 7.2(a).

- The obligation of assistance covers identifying the location of the point of impact, detection of the radioactive materials and debris and retrieval and clean-up operations.

B.3 Liability and Compensation

1. Responsibility

The International responsibility of States is set forth in Principle 8 and is based on article 6 of the *Outer Space Treaty* of 1967. States are responsible for their national activities in outer space including those involving the use of nuclear power sources. Such regime applies to activities conducted by governmental or non-governmental entities as well as by international organizations. Principle 8 and the issue of responsibility of States has been distinguished from the liability and compensation items although several delegations during the negotiations of the *Principles* has requested that all three issues be considered together notably France.[121]

2. Liability and Compensation

The liability regime applicable since 1992 does not differ from that previously established by the 1967 *Outer Space Treaty* and the *Liability Convention* of 1972. The absence of change has been noted by all authors while most also note that the existence of responsibility and liability provisions in a UN Resolution was also "unusual".[122] Such mention indicates the importance that States put in the

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[121] Principles Relevant to the Use of NPS, COPUOS Legal Subcommittee, *30th Sess.*, Annex I, UN Doc. A/AC.105/484, (1991) par. 15.

[122] Benkö, *supra* note 106 at 238.

elaboration and adoption of the *Principles.*[123]

As mentioned in the previous section on responsibility, article VI of the *Outer Space Treaty* establishes an international responsibility borne by States for their activities in outer space whether carried out by governmental or non-governmental entities. Such responsibility concerns damages caused to other parties or to their natural or juridical persons on the earth, in air or in outer space (art. VII). More precisely, the *Liability Convention* and the Principle of 1992 established the following.

a) Absolute Liability

The liability established by the *Liability Convention*, applicable to all activities, involving or not nuclear power, is the same and is absolute as set forth by article II of the Convention:

> A launching State shall be held absolutely liable to pay compensations for damage caused by its space objects on the surface of the Earth or to aircraft in flight.

The reasons for establishing such a strict regime was that during the negotiations of the Convention, it was recognized that the proof of fault or negligence would be difficult to bring.[124] Additionally, although space activities are lawful, and that applies for activities involving nuclear power sources (see *supra* Section A(1), the fact that such activities are considered "ultra-hazardous" activities calls for an absolute liability regime.[125]

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123 Benkö, *Ibid.*

124 UK Representative, in *Yearbook of the United Nations 1962* at 45.

125 I.H. Diedericks-Vershoor, "Similarities with and Differences between Air and Space Law Primarily in the Field of Private International Law" (1981) 172 RADI 317 at 352.

b) The launching and/or the procuring State is liable

Following the *Liability Convention*, Principle 9 provides that "each State which launches or procures the launching of a space object and each State from whose territory or facility a space object is launched shall be internationally liable for damage caused by such objects or their component parts." (Principle 9.1). It should be noted here that Principle 9 contains its own definition of the launching State which differs from that applicable to the other *Principles* (Principle 2.1 and Principle 2.2).

The term "procure" and "facility" are important to define as they will help determine in case of damage, which State(s) are responsible and should be held liable for a damage involving NPS. A State which "procures" a launch can be (1) a State financing partly or totally the launch, (2) a State requesting the launch, and (3) a State whose nationals financed or ordered the launch as article VI of the *Outer Space Treaty* provides that States are responsible for activities carried out in outer space by their nationals.[126] The term "facility" covers, among others and more importantly, launch facilities located in other territories than that of the State requesting the launch, facilities in outer space or in other territories outside the national jurisdiction of any State.[127]

Such definition of the launching States means that there are four possible liable States:

- The State which actually launches the object;
- The State which orders the launching of the object;

126 B.A. Hurwitz, *State Liability for Outer Space Activities* (Dordrecht, Neth.: Kluwer Academic, 1992) at 22.

127 C.Q. Christol, "International Liability for Damage caused by Space Objects" (1980) 74 A.J.I.L 347 at 359.

- The State in whose territory the launch takes place;
- The State owning the launching facility from where the object is launched.[128]

Therefore, all States mentioned above might be held liable for damages, separately or jointly, by victims of damages.

b) Damages covered

The definition of "damage" as well as further interpretation of what the definition actually covers is elaborated below.

Article I of the *Liability Convention* gives the definition of a damage, as meaning "loss of life, personal injury or other impairment of health, or loss or damage to property of States or of persons, natural or juridical, or property of intergovernmental organizations," which is interpreted as covering death, physical as well as psychological damages.[129]

Principle 9.3 added specific damages to the *Liability Convention* because such costs are entailed specifically by space activities involving NPS, such as "expenses for search, recovery and clean-up operations, including expenses for assistance received from third parties."

As already mentioned in the Section on Assistance, the fact that compensation covers also costs involved for the assistance of a third party reiterates the sovereign right of an affected State to choose the State from which assistance will be requested, without affecting its right to reimbursement of the costs from the

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128 Hurwitz, *supra* note 126 at 23.

129 *Ibid.* at 14.

liable State.

Indirect and delayed damages are also covered: another difficult issue regarding the damages covered both by the *Liability Convention* and the 1992 Principle related to the normally necessary direct link between a cause and the damage claimed by a victim, be it a State or a person. The possibility of compensation applies to direct and "immediate" damages, such as injuries, loss of property, financial losses, clean-up, recovery operations, etc. Regarding nuclear damages, and the same applies indeed to chemicals and other toxic products, the effects, the **damages, might be indirect**, difficult to quantify and **delayed.** For example, should a person be exposed to high levels of radiation, the consequences might be a cancer (direct but delayed), or the alteration of the person's genes, from which a child might suffer (delayed and indirect). The same applies to a country which might suffer immediate damage (to its population and environment) as well as delayed ones.

Although opinions differ[130] on this point, during the discussions within the UN COPUOS, "some delegations noted that it was important to have norms for international liability in that area and that such liability should include direct, indirect and delayed damage..",[131] such discussions show the spirit behind the elaboration of the *1992 Principles*, therefore indirect damages can be considered included in the damages covered by the *1992 Principles*. The particularities of nuclear damages not only to persons but overall to the environment calls for such interpretation.

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130 *Ibid.* at 16.

131 UN COPUOS, *Report of the COPUOS*, UN GAOR, 1986, Supp.20, UN Doc. A/41/20 at 13.

c) Compensation

Article 2 of the *Liability Convention* provides that the launching State is liable to pay compensation for damages caused by its space object, on the surface of the earth or to aircraft in flight. The amount of compensation granted is meant to restore the State "to the conditions which would have existed if the damage had not occurred."[132] However, article 5 of the *Rescue Agreement* seems to hold the launching State liable for the costs involved for the search, recovery and clean-up only if it requests the return of the remains from the State which conducted the operations. In the Cosmos 954 case, the issue of the *liability Convention* applicability was brought forward. Was there a damage in regard of art.1 of the same convention? Canada claimed there had been a "damage" to property through contamination. The devaluation of the Canadian property following the accident was "damage" within the meaning of the Convention, and was thus a legitimate basis for compensation. Although the settlement between Canada and the USSR did not answer most of the legal questions,[133] it comprises an "implicit recognition"[134] that the definition of damage in the Convention included 'damage to property of States" caused by nuclear contamination."[135] However, the former USSR did not clearly admit their liability, but paid compensation (Can.$ 3 million) to Canada which represented half of the Canadian claim.[136]

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132 *Liability Convention*, *supra* note 66, article 12.

133 Hurwitz, *supra* note 126 at 126.

134 *Ibid.*

135 J. Reiskind, "Towards a Responsible Use of Nuclear Power in Outer Space - the Canadian Initiative in the United Nations"(1981) 6 Ann. Air & Sp. L. 461 at 463.

136 *Protocol Between the Government of Canada and the Government of the USSR of 2 April 1981 for the Settlement of all Matters Connected with the Disintegration of Cosmos 954 in January 1978;* reprinted in Benkö & de Graaff, *supra* note 1 at 71.

Part III: Towards a Better Control of the Nuclear Power Sources Used in Outer Space Activities

Part III identifies the areas where revision is needed in order to improve the efficiency and comprehensiveness of the control of the use of NPS. Additionally, the conclusion of other types of instruments to better control such use has been suggested as more suitable than mere *Principles* which are perceived as too weak. Indeed, the outstanding issues remaining to create an efficient framework to the use of NPS in outer space relate first to the applicability of the *Principles* which includes their legal force, unclear geographical scope, and the fact that propulsion systems were voluntarily excluded. Some terms also remain unclear or not precisely defined such as the terms "launching State" and "Sufficiently High Orbit". Additionally, other criticisms relate to the fact that the *Principles* do not include the safety principles developed at international level for terrestrial applications of nuclear energy and that the link between space debris and NPS was not properly addressed. Several proposals to revise the *Principles* have been made, which vary from a mere introduction of new Principles to fill the existing gaps, to the larger elaboration of Standards and Recommended Practices, under the aegis of the United Nations, which would tackle all outstanding issues pertaining to international space activities.

A. Applicability of the *Principles*

1. Legal status of the *Principles*

With respect to the legal status of the *Principles* two issues have been raised. The first one relates to the terminology used, i.e., the use of the term "principle," considered inadequate by several authors, while the second issue pertains to the uncertainty of their legal force.

1.1 Terminology

The use of the term "principle" is considered not appropriate to qualify the set of measures adopted in 1992 and misleading. Principles of law are drawn from existing rules through a deductive process, and might then apply to concrete situations not expressly addressed by existing laws. A principle, as defined by A. Cocca, is "a fundamental truth, law, doctrine or a motivating force, upon which other are based.[...] In law, the principle is prior, accompanies or follows the legal provision and, if said provision lacks, it replaces it."[137] As such, principles form a legal basis recognized at the international level and applied by the International Court of Justice (hereinafter "ICJ") in the settlement of disputes in accordance with paragraph 1(c) of article 38 of the Statutes of the ICJ which provides that the Court applies "general principles of law recognized by civilized nations."

The *Principles* adopted in 1992 are the result of long discussions (over 10 year-long) however, they are not rooted in other texts, rules or practice. It is a set of new measures, mainly technical ones and do not correspond to any long-recognized and accepted principles. According to this doctrine, they would be measures falling within the mandate of technical and scientific organizations such as the IAEA or the ICRP. They could possibly be used as basis for a Convention but could not be accepted as the appropriate legal framework to regulate the use of NPS in outer space.[138]

During the negotiations of the *Principles*, their legal status was raised several times but was always postponed to future debates. In 1991, the discussions on this subject resumed and the problem was addressed by the co-authors of a Working

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137 A.A. Cocca, "Are the Principles on the Use of NPS in Outer Space a Progress in Space Law?" (1993) *36th Colloquium on the Law of Outer Space* 255 at 256.

138 See Cocca, *Ibid.*

Paper presented by Canada and 8 other countries.[139] The co-authors were of the opinion that the *Principles* constitute "strong recommendations" to achieve some objectives without bearing the binding force of treaties or other international agreements.

However, this said, the fact that the *Principles* were adopted by consensus by the UN COPUOS and subsequently adopted by a Resolution of the United Nations General Assembly, might give them a higher weight than a "strong recommendation," and might indeed be the start of a custom.

1.2 United Nations General Assembly Resolutions and Customary Law

The General Assembly does not have the authority to adopt and implement binding legal instruments on its members, it is not a "world legislature."[140] However, it derives from Article 10 of the UN Charter the power to study legal issues in the view of progressively developing international law and its codification. "The General Assembly's powers to recommend actions that enhance the norm-creating process of international law plainly serve a prescriptive purpose."[141] Although non-binding, UN Resolutions have served as a basis for the development and adoption of international treaties. Indeed, most of the space-related treaties started by being COPUOS decisions which then were adopted by UN General Assembly resolutions, to eventually become treaties or conventions (e.g., The *Outer Space Treaty* of 1967).[142] Although the General Assembly does not and cannot codify law through

[139] The countries were Germany, China France, Italy, The Netherlands, UK, Sweden and Czechoslovakia. UN Doc. A/AC.105/C.2/L.184, April 8 1991.

[140] C.C. Joyner, ed., *The United Nations and International Law*, (Cambridge: ASIL and Cambridge University Press: 1997), 441.

[141] See Joyner, *Ibid.*

[142] See Joyner, *Ibid.* at 444.

resolutions, even when they are adopted unanimously, by consensus (as is the case of the *Principles*), repeatedly or without formal opposition from any State, its resolutions "[...] can function as instruments to distill and crystallize into tangible form the international community consensus regarding a customary norm."[143]

There are two essential elements of a custom: the objective or material element, that is the repeated accomplishment (*consuetudo*) of a practice which might initially only be a usage. The second element is the subjective, psychological or social element, i.e., the conviction that the accomplishment of such practice is mandatory, that it is an exigency of the law (*opinio juris sive necessitatis)*.

International acts, as long as they emanate from international legal subjects, may constitute the start point of customs, if they aim at becoming general or indeed even universal. Such principle was admitted by the International Court of Justice in the cases of the *North Sea Continental Shelf.*[144] International organizations' acts, and notably the Resolutions of the General Assembly Resolutions as they are immediately known and accepted by a large number of States, have a universal nature which may accelerate the creation of a custom. Through cases submitted to the International Court of Justice, the Court has identified several criteria refining the definition of the material and subjective elements of customs.

As part of the criteria identified by the International Court of Justice concerning the creation process of custom, is the uniform repetition in time of specific acts which permits to single out a constant and uniform practice. In this respect, the Court ruled as follows in the case *Military and Paramilitary Activities in and against*

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143 See Joyner, *Ibid.* at 446.

144 *North Sea Continental Shelf Cases*, [1969] I.C.J. Rep. 41-45.

Nicaragua:[145]

> In order to deduce the existence of customary rules, the Court deems it sufficient that the conduct of States should, in general, be consistent with such rules,...

Moreover, the fact that a practice is deviated from does not constitute sufficient grounds to reject that such practice constituted an established custom. In this respect the Court ruled that:

> The Court does not consider that, for a rule to be established as customary, the corresponding practice must be in absolutely rigorous conformity with the rule. [...] If a State acts in a way prima facie incompatible with a recognized rule, but defends its conduct by appealing to exceptions or justifications contained within the rules itself, then whether or not the State's conduct is in fact justifiable on that basis, the significance of that attitude is to confirm than to weaken the rule.

The time a practice has to exist prior to recognizing the existence of a custom has been examined by the Court to determine whether or not there is a custom. In this respect, the Court (i) does not require that a practice exists for many year to recognize the existence of a custom but (ii) places the importance on the States that followed such practice. Thus, not all States must participate in the practice but at least the representative/interested States. Regarding point (i), in the *North Sea Continental Shelf Cases* the Court ruled that:

> [...] [A]n indispensable requirement would be that within the period in question, short though it might be, State practice, including that of States whose interests are specially affected,

145 *Military and Paramilitary Activities in and against Nicaragua (Nicaragua v. United States of America)*,[1986] I.C.J. Rep. 88.

> should have been both extensive and virtually uniform ...[146]

With respect to point (ii), i.e., whether a practice must be adopted by all States in order to qualify as custom, article 38 paragraph 1.b) of the Statutes of the International Court of Justice, indicates that, as far as general customary rules are concerned, they result from a general practice, not unanimous (which would be virtually impossible and unrealistic.) In the above-mentioned cases of the *North Sea Continental Shelf*, the Court stated that:

> With respect to the other elements usually regarded as necessary before a conventional rule can be considered to have become a general rule of international law, it might be that, even without the passage of any considerable period of time, a widespread and representative participation in the convention might suffice in itself and, provided it included that of States whose interests were specially affected.[147]

This last criteria outlined by the Court, in order to decide whether the *opinio juris* condition is met is of particular interest for the *1992 Principles.*

It has been further suggested by the doctrine that, when in presence of a resolution, there is a presumption of the existence of a custom if (i) States "whose interests [are] specially affected" respect a specific practice, (ii) the text contains either a clear intention that it is to be the law or the expression of a "belief" that a rule is introduced and, (iii) if such resolution is adopted unanimously or by consensus.[148]

Such intention or belief would satisfy the subjective element of customary law

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146 *North Sea Continental Shelf cases*, *supra* note 144, 189, at 43.

147 *Ibid.*

148 C.F. Amerasinghe "Principles of the Institutional Law of International Organizations" (Cambridge University Press 1996) 219.

(*opinio juris*).[149] Such expression of belief seems to be present in paragraph 6 of the Preamble of the *1992 Principles* which reads as follows:

> Affirming that this set of Principles applies to nuclear power sources in outer space devoted to the generation of electric power on board space objects for non-propulsive purposes, which have characteristics generally comparable to those of systems used and missions performed at the time of the adoption of the Principles.

In theory it would thus be possible that "... (1) a unanimous resolution constitutes the practice of 160 States and (2) a statement in the resolution that its contents are law constitutes *opinio juris* . . ., [this forming the basis for an] . . instant custom. The idea of international custom has also rested on the view that an *opinio juris* expressed by the entire community of States will itself validate a rule of law."[150]

Although the object of this paper in general and of this section in particular is not to demonstrate that the *1992 Principles* are indeed customary law, it could however be noted here that some elements of the *Principles* are already generally applied and recognized by "the interested States," notably some of the new "rules" introduced by the *1992 Principles* relating to Safe Use, Guidelines on Design, Safety Assessment etc. (see *supra* Part II, Sections B.1 and B.2.) States and their space agencies (see Part III(D.2) have also adopted self-regulations in order to control the risks of collision and of creation of space debris.

2. Propulsion Systems

With respect to propulsion systems, States are faced with what is described by M.

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149 See Amerasinghe, *supra* note 148, at 218.

150 Abi-Saab G., "The Development of International Law in the United Nations"24 Revue Egyptienne de Droit International (1968) 100, cited in Amerasinghe, *supra* note 148 "Principles of the Institutional Law of International Organizations"(Cambridge University Press 1996) 219.

Lachs in a most striking manner on the progressive development and codification of international law:

> In law we must beware of petrifying the rules of yesterday, and thereby halting progress in the name of progress. If one consolidates the past and calls it law he may find himself outlawing the future. If, on the other hand, one codifies rules that have not yet matured one postulates the future and calls it law; the present will not heed and those rules will be still-born.[151]

Contrarily to the issue of the geographical scope of the 1992 *Principles* (see *infra*, point 3), the present issue is clearly addressed by the *Principles*, both in paragraph 2 of the Preamble and in Principle 3: NPS used as propulsion systems are excluded from the scope of the *Principles* (see *supra*, Section on the Legality of the use of NPS.)

Although the technology allowing the use of nuclear power for propulsion is not yet completed and mastered, research in this area is intensive and full knowledge on the matter is not out of reach (see *supra*, Section on Nuclear Propulsion). As noted by Benkö and Gebhard, "the work of the UN COPUOS on NPS is not *yet* finished since the *Principles* deal with NPS systems which are operational at present."[152] In this respect, it has been further argued that failure to eventually include propulsion systems to the scope of the *Principles* will only limit their effectiveness[153] since, as technology progresses, States will be left with a set of technical standards, principles, applying to obsolete technologies. Also, elaborating Principles addressing the issue of propulsion would create confidence and allow more funding

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151 Speech made on 12 October 1973, at the 28th session of the General Assembly, at a special meeting to commemorate the 25th anniversary of the Int'l. L. Com., (12 October 1973) UN Doc. A/PV.2151, in Jasentuliyana, *supra* note 95 at 491.

152 Benkö & Gebhard, *supra* note 1 at 37.

153 N. Jasentuliyana, "An Assessment of the United Nations Principles on the Use of Nuclear Power Sources in Outer Space" (1993) *32d Colloquium on the Law of Outer Space* 312 at 316.

to be devoted to projects in this field.[154]

3. Geographical scope of the *Principles*

The title of the *1992 Principles* indicates that it applies to the use of NPS in "Outer Space". The set of principles refers to Outer Space and Principle 3 *Guideline and Criteria for Safe Use*, does not refer to specific areas of outer space but, rather, sets forth standards for the use of NPS. Accordingly, NPS may be used for/in:

- Interplanetary missions (Principle 3(2.1);
- Sufficiently High Orbit, which is defined as "one in which the orbital lifetime is long enough to allow for a sufficient decay of the fission products... that the risks to existing and future outer space missions and collision with space objects are kept to a minimum." (Principle 3(2.2);
- Low Earth Orbits, provided that the reactors be later stored in a sufficiently high orbit.

Thus, no geographical area is specifically mentioned as falling under the scope of the *Principles*.

Although the issue is not yet in debate due to the fact that concrete applications belong more to the future, another issue of interest is the application of the *Principles* to the Moon and other celestial bodies. A.D. Terekhov indicates that the *travaux préparatoires* of the *Principles* show that "the main objective of the drafters

[154] Benkö & Gebhard, *supra* note 1 at 71.

was the elaboration of guidelines for the use of NPS on Earth orbits,"[155] and the most important seemed to be the protection of the biosphere and of all human lives on Earth, therefore leaving out the precise definition of the geographic areas concerned by the Principles. It is recognized that they apply to all celestial bodies and to the Moon as "no provision of existing law prevents the use of nuclear reactors on the Moon. Some language appears to regulate their use, however, and other provisions would affect their launch and journey" to the Moon or any of the celestial bodies, but no express prohibition exists.[156]

B. Definitions of terms

This section focuses on the definitions and terms identified as vague and which might "weaken the impact of highly important criteria."[157] Such terms are, for example "launching State" and "Sufficiently High Orbit" which need to be refined, although a better definition of the launching State might need to take place in a larger framework than within the discussions on the *Principles*.

1. The two definitions of a launching State contained in the 1992 *Principles*

The importance of a better definition of the launching State lies in the fact that actions, and legal duties such as preventive measures, mitigation actions, responsibility, liability and compensation are directly attached to the launching State. The *1992 Principles* adopted a **dual approach** to the problem and introduced two definitions, both unclear.

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155 A.D. Terekhov, "Review and Revision of the Principles Relevant to the Use of Nuclear Power Sources in Outer Space" (1993) *36th Colloquium on the Law of Outer Space* 336 at 341.

156 M.S. Smith, "Legal Aspects of Using Nuclear Reactors on the Moon" (1992) *35th Colloquium on the Law of Outer Space* at 312.

157 Christol, *supra* note 109 at 247.

▸ **The first approach**, set forth in **Principle 2(1)** and applicable to *Principles* 4, 5, and 7, defines the launching State as "the State which **exercises jurisdiction and control** over a space object with NPS on board at a given point in time relevant to the principle concerned" [emphasis added]. The duties of the launching State as per this definition encompass the (1) Safety Assessment (Principle 4), (2) notification of a launch (Principle 4), and (3) Assistance to States to eliminate the (potential) harmful effects of re-entry of space objects with NPS on board.

While drafting the *Principles* the problem in defining who was to be considered the "launching State" of Principle 2(1) arose from the fact that objects may be launched from the territory of States who are providing their territories and launching installations to other States, manufacturers, designers etc. of a space object with NPS on board. Such State would be unlikely to have all detailed information about the object or on the power source on board, let alone be involved in operating or handling the object to be launched. The State manufacturer, designer etc. might, in addition, not be willing to consider that it does not retain jurisdiction and control over an object manufactured and designed by it to the benefit of the launching facility provider. Such was the case, during the negotiation of the *Principles*, of the US who claimed that US law would exclude that jurisdiction and control of a space object containing NPS be transferred to the launch facility provider. On the other hand, others (e.g., France) argued that countries whose territories were used for the launching of space objects were the ones who retained the final decision to launch or not and who had the only and exclusive "port authority," and should have full knowledge of what is launched from their sites.[158]

▸ **The second approach**, specifically attached to the liability and compensation regime established by the *1992 Principles*, is the State "**that**

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[158] Benkö & Gebhard, *supra* note 1 at 58.

launches or procures the launching of a space object" (Principle 9)[emphasis added]. It is not clear what either term refers to. Resorting to other space treaties and conventions does not solve the problem as either the launching and procuring State are considered two different entities (*Outer Space Treaty*, art. VII) or the same ones (1972 *Liability Convention* article 1c and article 1a of the 1975 *Registration Convention*).

A common acceptance of the term procurement State exists as defined by Böckstiegel: "most authors seem to favor the view that a State at least has to be somehow actively involved by **requesting, initiating, or at least promoting** the launching of a particular space object in order to consider it as having "procured" the launching."[159]

The major problem relating to the discrepancies between the definitions provided by the space conventions/treaties and the *1992 Principles* relates to the identification of the rights and duties of the procuring State, the legal relationships between the launching State and the procuring State and the legal relationships between the procuring State and non-governmental entities which would have initiated i.e., "procured" (see above definition of procurement) the launching, of an object in outer space.[160] Indeed, in accordance with article 7 of the *Outer Space Treaty* of 1967, States are responsible for activities conducted in outer space by their nationals. Although this entails that a non-governmental organization may procure a launch and that its State would then be responsible and liable for damages incurred by the private entities' activities, it does not solve the question

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159 K.-H. Böckstiegel, "The terms "Appropriate State" and "Launching State" in the Space Treaties - Indicators of State Responsibility and Liability for State and Private Activities" (1991) *34th Colloquium on the Law of Outer Space* 13 at 15.

160 Christol, *supra* note 109 at 248

for example of the legal relationships between such entity and its State.[161]

Although the launching of space objects with NPS on board by private entities is not yet on the agenda as the use of nuclear energy is State-controlled, private initiatives to encourage the launching of space objects exist, such as the recently created X-Prize foundation which promises a US$ 5 million award to the first person or group of persons who could succeed in launching manned objects to 100 km suborbital apogee.[162] The fact that engineers from different countries could possibly participate in one same project would not facilitate the solution of liability issues in case of damage.

2. Definition of "sufficiently high orbit" (Principle 3)

The height at which a sufficiently high orbit might be found is not precisely set as Principle 3 indicates only that it is "one in which the orbital lifetime is long enough to allow for a sufficient decay of the fission products [...] and [...] the risks to existing and future outer space missions and collision with other space objects are kept to a minimum." (Principle 3(2.2).

Such provision provides only guidelines for safe use as opposed to a precise definition of the orbit in question. Most probably, a precise value defining in miles or kilometers the sufficiently high orbit "would have had to be based on so many worst case assumptions that the cost involved in reaching that height were very likely to be unjustified."[163] Instead, the States have agreed to place the responsibility on the designers and manufacturers, which will have to decide, in accordance with the technical specifications of the object launched and the orbital

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161 *Ibid.*

162 On public's loss of interest in space activities, see Diamandis, *supra* note 48.

163 Benkö, *supra* note 106 at 235.

parameters, what a sufficiently high orbit is.

The issue pertains not only to the difficulty of defining such orbit but more generally to the question of space debris (see *supra*). The UK, supported by other delegations participating in the UN COPUOS, argues that "there is no adequate definition of a safe orbit because, to date, the problem of space debris has not been properly addressed."[184]

C. Justification and Minimization of risks entailed by the use of NPS in Outer Space

The refinement of the safety principles applicable to activities involving nuclear power sources, similarly to those developed for terrestrial applications is a necessary element to be inserted in a revised set of Principles. The leader in such proposal is the United Kingdom, through its participation in the work of the COPUOS, and in particular in the Scientific and Technical Subcommittee. The cornerstone of their claim for improving safety are the concepts of global justification - of the risks taken by launching nuclear in outer space - and the concept of minimization of the risk to individuals which aims at maintaining the risks below the acceptable limits, at a reasonable *de minimis* level.

1. Concept on Justification

The introduction of the concept of justification applicable to terrestrial nuclear power sources has been proposed since the revision of the *1992 Principles* has started to be discussed, and has officially been addressed by UK and Northern Ireland through two Working Papers submitted to the Scientific and Technical

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184 UN COPUOS, ***National Research on Space Debris, Safety of Nuclear-Powered Satellites, and Problems of Collisions of Nuclear Power Sources with Space Debris***, UN GAOR, 1994, UN Doc. A/AC/105/593 [hereinafter UN Doc. A/AC.105/593].

Subcommittee of the UNCOPUOS.

The concept of justification is the requirement that **global net positive benefits result from activities involving nuclear power sources** in outer space.

The development of new technologies and their applications has always entailed some risks not limited to the explorers or scientists but extended to the general public through the application of these technologies to human activities. In order to maintain a high level of safety and reduce the risks attached to commercial and industrial applications of these technologies (e.g. aviation), general principles of safety apply. Such long-developed safety principles apply also to space activities. As indicated in Part II (see *supra* Section on the ICRP guidelines and Safety Standards of the IAEA at 35), the justification of a net positive benefit is included in the ICRP Recommendations of 1990[165] and in the IAEA standards for the safety of nuclear installations.[166]

Thus, no practice involving exposure to radiation should be adopted unless it produces a benefit that outweighs the harm it causes or could cause. Therefore, the concept of justification applies in parallel with the concept of limitation of exposure (see *supra*). At the same time, the IAEA's guidelines have for general safety objective "the protection of individuals, society and the environment against radiological hazards."

The UK argues that the justification of net positive benefits must be done not only **globally but also at national level** as well as **individual level** due to the fact that the risks related to space activities are extended to all nations. Since most

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165 ICRP 1990 Recommendations, *supra* note 74.

166 "Safety of Nuclear Installations" Safety Series 110 STI (Vienna: IAEA, 1993).

catalogued orbiting objects (see *supra* p.20) have orbital inclinations in the range of 60-110 degrees, most countries are at risk of re-entry impacts. The risks of re-entry for launching countries is offset by the benefits its population may gain from the launching of objects with NPS on board. However, for non-space countries, there are no or little benefits. That is why the British request that the justification be also done for each country.

The **global benefits** of the use of NPS are not known but are perceived higher than the risks (e.g. programmes of settlements on planets, deep-space missions (ex. Cassini), the space station through for example, the knowledge gained and its applications (medicine, education, science, industry, communications etc.) or as representing an example of international endeavor and cooperation. Globally, the type of **risks** incurred by countries are related to costs of the recovery of falling objects or components thereof, clean-up operations, damage to population, environment, etc.

At **national level**, if the benefits may seem obvious (e.g., telecommunications services) they are not evenly distributed (developing countries). A possible way to justify the use of NPS would be for example to develop and increase the telecommunication networks of countries who are for now left behind.

The UK comments that "the question of international endorsement of the justification for future missions involving space NPS remains to be addressed. Until the safety culture for space NPS is extended to the international level it is suggested that justification for future nuclear space missions, demonstrating quantitatively a net positive benefit, should be presented to the Scientific and

Technical Subcommittee prior to the launch."[167]

2. Minimization of the individual risk to radiological exposure to as low as reasonably achievable

The concept of reducing individual risks to as low as reasonable achievable (ALARA principle) is also present in the ICRP guidelines and IAEA standards (see *supra* p.35). In cases where the risk is shared by populations which are not receiving any benefit, the ICRP recommends that "the total collective dose equivalent should be kept below that which would have applied had the cost benefit assessment been confined to the population that received the benefit" (see dose limits *supra* at 35).

The *de-minimis* level would need to be introduced in the Principle, as at the moment, Principle 3 refers to dose limits exclusively which are acceptable for populations, individuals who gain a certain benefits from the activities, however not to the individuals of countries who gain no or little benefits.

D. Space Debris

1. Acknowledgment of the Problem by States

As seen in Part I(B.2), many space debris are orbiting both in LEO and GEO, and represent a potential danger to all space objects but even more when carrying NPS on board. It should be noted however, that a study conducted in order to predict the long-term growth of the satellites and debris population in LEO concluded that catastrophic growth of collision fragments should not occur for another 10 years

167 UN COPUOS, ***National Research on Space Debris, Safety of Nuclear-Powered Satellites, and Problems of Collisions of Nuclear Power Sources with Space Debris – Reply received from the United Kingdom of Great Britain and Northern Ireland***, UN GAOR, 1995, UN Doc. A/AC.105/593/Add.3 at 8 [hereinafter UN Doc. A/AC.105/593/Add.3].

with the current level of debris deposition into orbit.[168] The same opinion emanates from the IAA position paper on orbital debris[169] although special attention should be brought to the location of deposition of future debris into orbit as this influences greatly on the growth of the debris population.

States have been aware of the debris risk for quite some time now. In 1980, the International Astronautic Federation (IAF) issued a study on behalf on the UNCOPUOS on the efficient use of the GEO where debris management was addressed. Other position papers were then issued, notably by the American Institute of Aeronautics and Astronautics in 1981, and at the same time, NASA started a ten-year plan to address key issues, which comprised debris control. Workshops were organized on the matter both by the US and later by ESA. In 1988 the US National Space Policy emphasized the need for a minimization of the creation of space debris. ESA established a working group on the subject and issued a first report in 1988. Japan also intervened in this field and the Japanese Society for Aeronautical and Space Sciences founded the Japan Space Debris Group, which reported in 1992. The UN General Assembly, in its Resolution 48/39 of 10 December 1993 considered essential that Member States pay more attention to the problems of collisions of space objects, including NPS, with space debris, and other aspects of space debris (paragraph 27), and invited members to report to the Secretary-General on a regular basis with regard to national and international research concerning the safety of nuclear-powered satellites (paragraph 14). The COPUOS in the Report of its 37th session (A/49/20, para. 77) agreed that member States and relevant organizations should be encouraged to provide information on practices they had adopted and that had proved effective in minimizing the creation of space debris. The Secretariat of the UNCOPUOS

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168 C.R. McInnes, "An Analytical Model for the Catastrophic Production of Orbital Debris" (1993) 17 *ESA J.* no.4 295.

169 IAA Position Paper, *supra* note 41.

prepared a document on the basis of information received from the above mentioned States and organizations in December 1994.[170]

The Russian Federation in its "reply" to the UN COPUOS in 1995 estimated the probabilities for collision between a reactor located in a circular orbit of 950 km and space debris greater that 0.5 cm in size to be one in approximately 75 years. For space debris greater than 15 cm the Russian Federation "predict[s] a substantially lower probability of collisions with space debris of large dimensions.."[171]

Since 1997, the issue of NPS and space debris are inter-related as recognized by the Report of COPUOS in its recommendations and decisions relating to the use of nuclear power sources in outer space:

> The Committee agreed with the Scientific and Technical Subcommittee that Member States should continue to be invited to report to the Secretary-General on a regular basis with regard to national and international research concerning the safety of space objects with nuclear power sources, that further studies should be conducted on the issue of the collision of orbiting space objects with nuclear power sources on board with space debris and that the Subcommittee should be kept informed of the results of such studies.[172]

2. Actions Taken by States: Self-Regulation

The issue remains: no international regulation exists so far to control and limit the

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170 UN Doc. A/AC.105/593, *supra* note 164.

171 UN COPUOS, *National Research on Space Debris, Safety of Nuclear-Powered Satellites, and Problems of Collisions of Nuclear Power Sources with Space Debris – Reply received from the Russian Federation*, UN GAOR, 1995, UN Doc. A/AC.105/593/Add.2. at 7 [hereinafter UN Doc. A/AC.105/593/Add.3].

172 UN COPUOS, *Report of the COPUOS*, UN GAOR, 52d sess., 1997, Supp. 20, UN Doc A/52/20 at para.81 [hereinafter UN Doc. A/52/20].

growth of space debris in outer space. Most space countries restrict themselves from further creating/depositing space debris, through self-imposed guidelines and regulations, either at State level or at space-agency level. Such self-imposed measures appear through all the information provided by States on the request of the UN COPUOS.[173]

The **Canadian RADARSAT** was the first unmanned satellite to incorporate shielding to counter the collision hazard. Such achievement appears in the country's communications to the COPUOS on measures and practices taken to maintain safety of a NPS on board a spacecraft colliding with space debris. Canada further informed the UNCOPUOS that within its programme of preventive measures, instructions were required to be given to designers so that RADARSATs had a system level requirement so as to contain any solid debris resulting from the operation of a restraint/release mechanism.[174]

INTELSAT for example has decided to adopt two type of measures for its communication satellites: (1) boosting satellites into orbits at least 150 km above GEO at the end of their operational lifetime and (2) discourage their manufacturers from using design where spacecraft components are jettisoned, especially near the GEO. Other measures include shielding of the critical components of the spacecraft, or a preventive measure to avoid collision with debris larger than 1 cm is to alter the orbit of the object. Such measure requires a highly manoeuvrable satellite and accurate equipment evaluating the spacecraft position, so as to alter the position at the right moment. The position prediction is a very important element for the Space Station for example as the other preventive measure, i.e., alteration of orbit, will be difficult to conduct since the Station manoeuvrability will be limited

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173 *Ibid.* at para. 79.

174 UN Doc. A/AC.105/593, *supra* note 164.

to a few modifications per year.[175]

ESA has also voluntarily adopted several measures of space debris prevention such as a re-orbiting of GEO satellites, a passivation of the Ariane Third stage, a reduction of mission-related objects and the shielding of manned vehicles (such as the ESA module planned for the Space Station which will be shielded against particles of about 1 cm.)[176]

The other possibility to limit the creation of space debris is international regulation which would ensure more generally that the responsibility for debris mitigation is equally borne by all space users. However, although the problem of space debris is a "priority item"[177] for the next session (1998) of the Scientific and Technical Subcommittee of the COPUOS, we are still at a stage of thorough technical research and not regulation. A positive aspect is that the Scientific and Technical Subcommittee has developed a Multi-year Plan since 1995[178] and in 1998, the Committee will define the final stage of the Plan i.e, on space debris mitigation measures. The Subcommittee will subsequently finalize a report on the issue of space debris in 1999.[179]

E. Proposed Forum and Methods for Revision

While the proposed forum to improve the regulation relating to the use of NPS in outer space is generally agreed on, several suggestions concerning the methods

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175 UN Doc. A/AC.105/606, *supra* note 43 at para.25.

176 *Ibid.* at para.30.

177 UN Doc. A/52/20, *supra* note 172 at para.91.

178 UN COPUOS, *Report of the Scientific and Technical Subcommittee on the Work of its 32d Session*, 1995, UN Doc. A/AC.105/605 at para. 83.

179 Multi-year Plan, *supra* note 172 at 89.

of improvement of the current rules applicable to space nuclear activities vary. The proposed methods for revision vary in accordance to the objectives that the authors of such proposals attach to the revision itself, i.e., improving the *1992 Principles* by filling the gaps, adding new Principles or link the problems of the use of NPS in outer space to a more general but essential existing problem relating to space law i.e., existing space law is made out of "general rules without providing specific standards or procedures by which the treaties are to be implemented and by which space activities can be controlled."[180]

1. The United Nations COPUOS

The favorite forum to implement the proposed modifications of the *Principles* or more generally of the rules applicable to the use of Nuclear Power sources in outer space, is the United Nations clearly because it gathers most, if not all, States and has well and long-established procedures and rules for discussions and negotiations and acts as a coordinator of all on-going discussions concerning space activities. Setting up a new and different forum would only postpone the work. Therefore the **Committee on Peaceful Uses of Outer Space and its two Subcommittees** would continue its tasks. The UN COPUOS has managed to have five treaties and four sets of Principles adopted within 25 years,[181] because it started its work while space activities were developing. The corresponding extent of revision of the existing regulation on the use of NPS in outer space would be to either add new principles or modify the existing ones within the forum of the

180 Jasentuliyana, *supra* note 95 at 379.

181 Besides the *1992 Principles*, the General Assembly has also adopted *The Declaration of Legal Principles Governing the Activities of States in the Exploration and Use of Outer Space*, Resolution 1962 (XVIII) of 13 December 1963; *The Principles Governing the Use by States of Artificial Earth Satellites for International Direct Television Broadcasting*, Resolution 37/92, annex, of 10 December 1982; and the *Principles Relating to Remote Sensing of Earth from Space*, Resolution 41/65, annex, of 3 December 1986.

UNCOPUOS. The United Kingdom proposed a "fresh start" in its Working Paper,[182] meaning that a revised set of Principles would be developed, would recognize the limitations of the first set of Principles and introduce principles on the most recent developments in space technologies, on safety of terrestrial nuclear installations, such as the concept of justification and of the *de-minimis* level. The proposed modifications of the United Kingdom mostly refers to the technical aspects of the safe use of NPS although it must be recognized that the country also proposes the more general establishment of a "safety culture" as was and still is developed by the IAEA to train managers and all persons involved in nuclear activities.[183] More generally, the political scene has considerably changed and the relations between the States has modified the negotiations scene and the States' interests, which renders the establishment of new rules very complex. As noted by N. Jasentuliyana, "[m]ore recently, [...] the momentum of space law legislation has slowed down."[184] With such a background the proposed improvements of regulations applying to the use of NPS will have to adapt to the "new" international context.

The adoption of the *1992 Principles* and the other items discussed within the COPUOS such as space debris, remote sensing etc., shows how much the debate has shifted from the definition of general laws of international space law, to focused discussions on specific technical aspects of space activities, which also makes it difficult to reach consensus as some States are opposed to imposing limits to their own activities and to giving up some of their interests.[185]

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182 UN COPUOS, "Revising the Safety Principles for Nuclear Power Sources in Space", Paper submitted by the UK and Northern Ireland to the STS, UN GAOR UN Doc. A/AC.105/C.1/L.192 at 2 [hereinafter UK Paper].

183 UK Paper, *supra* note 182 at 7.

184 Jasentuliyana, *supra* note 95 at 382.

185 *Ibid.* at 384.

2. An International Specialized Forum

A wider solution than the one described above in its objectives, is based on the fact that most space treaties elaborated general rules leaving out a certain number of vague concepts and recommendations to be properly defined. As described earlier, the international community is now faced with new problems of more of a technical nature such as nuclear power sources, space debris, which require an extensive technical work prior to establishing appropriate regulations.[186] In such a context where basic principles and law have been elaborated, where discussions are of a more and more technical nature and where issues at stake are increasingly inter-related (i.e., space debris and nuclear power sources) a very specialized and technical forum seems to be needed.

From this derives the proposal to create an international organization (in the framework of a Convention) exclusively dealing with space activities and in charge of establishing rules which States would have to abide by.[187] Such organization would be composed of a group of technical and legal experts whose task would be to study and define Standards and Recommended practices on various space activities such as space debris, NPS, search and rescue, space navigation, manned space flights, space environment etc. and would become the body of reference in terms of applicable standards and practices. Such organization would be similar to the existing International Civil Aviation Organization which allowed harmonization of most existing legislation in aviation. Some of the proposed recommendations and practices might already exist for terrestrial applications (e.g., nuclear activities: the IAEA; environment: the Global Environment Facility and all environment conventions and bodies which have flourished in the recent years,

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186 Jasentuliyana, *supra* note 95 at 379.

187 Baker, *supra* note 79.

etc.) and would require the adaptation of such recognized standards and practices for space activities. The impetus given by the creation of such an organization would not fail to provide the world with a legal framework, albeit Principles, International Treaties or Agreements or Standards and Recommended Practices. The legal framework achieved by ICAO and the links created with other international organizations led to the situation where any State willing to be part of the international aviation business must comply with ICAO's rules.

The question is whether such organization is really needed and/or really wanted by the States given the current context in which the role of the United Nations is being redefined and refocused. It is also brought forward that "any restrictions on space nuclear power are more likely to be self-imposed, in the case of the USSR, or due to internal political or legal constraints, as in the USA."[188] But the function of harmonization and neutral forum for international discussions and regulation will still be needed and, above all, discussions on the use of nuclear power sources in outer space integrated to the other outstanding legal issues relating to space activities.

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188 Aftergood, *supra* note 102.

Conclusion

All along the paper we have seen that nuclear energy may legally be used for different applications such as providing heat and electricity for space objects. Another application, propulsion, has voluntarily been left out of the existing legal framework as it is not yet feasible although extensive research exist and will continue to be done on the subject. The use of nuclear power sources has luckily not had dramatic consequences so far on human environment and lives, despite the occurrence of many incidents/accidents of which the Cosmos 954 accident had the most severe consequences, but its use entails large risks for the world community. International instruments regulating its use exist, dealing either directly or indirectly with nuclear power sources. However, the most recent and comprehensive regulation results from the adoption of the *1992 Principles* by the United Nations General Assembly, which, despite their non-binding legal force, have set principles which States have so far complied with. The Principles themselves are imperfect because a balance between technical issues and the definition of relevant applicable legal rules had to be found, to set up an efficient control and safe use of nuclear energy in outer space, without ignoring the technological progress that might be accomplished after their adoption. Such balance is considered more and more inappropriate as the *Principles* lack precision in the definition of certain concepts and terms and fail to incorporate accepted international standards and principles applying to nuclear energy for terrestrial applications.

A solution to correct the imperfections has not yet been found and its objectives hesitate between a mere revision of the *1992 Principles* which would be more limited than another approach aiming at setting up an international body or entrusting the UN COPUOS, with the elaboration of Standards and Recommended

Practices for all outstanding technical space-related issues.

It is important to note that through the development of space law and in particular of regulations applying to the use of nuclear power sources in outer space, "[t]he dialogue between law, science and technology, at a crucial point of the development of all of them was thus established, a dialogue which is so essential in many [..] spheres of international relations."[189] Such "dialogue" will and need to continue further, at an international level, to create a proper and adaptable regime to future space activities, involving or not nuclear energy.

189 M. Lachs, cited in Jasentuliyana, *supra* note 42 at 519.

Annex I: Principles Relevant to the Use of Nuclear Power Sources in Outer Space

(Text approved by the Committee on the Peaceful Uses of Outer Space at its thirty fifth session (1992) and adopted by the General Assembly at its forty seventh session (1992) by Resolution 47/68 of 14 December 1992.

Preamble

The General Assembly,

Having considered the report of the Committee on the Peaceful Uses of Outer Space on the work of its thirty-fifth session and the text of the Principles Relevant to the Use of Nuclear Power Sources in Outer Space as approved by the Committee and annexed to its report,

Recognizing that for some missions in outer space nuclear power sources are particularly suited or even essential owing to their compactness, long life and other attributes,

Recognizing also that the use of nuclear power sources in outer space should focus on those applications which take advantage of the particular properties of nuclear power sources,

Recognizing further that the use of nuclear power sources in outer space should be based on a thorough safety assessment, including probabilistic risk analysis, with particular emphasis on reducing the risk of accidental exposure of the public to harmful radiation or radioactive material,

Recognizing the need, in this respect, for a set of principles containing goals and guidelines to ensure the safe use of nuclear power sources in outer space,

Affirming that this set of Principles applies to nuclear power sources in outer space devoted to the generation of electric power on board space objects for non-propulsive purposes, which have characteristics generally comparable to those of systems used and missions performed at the time of the adoption of the Principles,

Recognizing that this set of Principles will require future revision in view of emerging nuclear-power applications and of evolving international recommendations on radiological protection,

Adopts the Principles Relevant to the Use of Nuclear Power Sources in Outer Space as set forth below.

Principle 1. Applicability of international law

Activities involving the use of nuclear power sources in outer space shall be carried out in accordance with international law, including in particular the Charter of the United Nations and the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies.

Principle 2. Use of terms

1. For the purpose of these Principles, the terms "launching State" and "State launching" mean the State which exercises jurisdiction and control over a space object with nuclear

power sources on board at a given point in time relevant to the principle concerned.

2. For the purpose of principle 9, the definition of the term "launching State" as contained in that principle is applicable.

3. For the purposes of principle 3, the terms "foreseeable" and "all possible" describe a class of events or circumstances whose overall probability of occurrence is such that it is considered to encompass credible possibilities for purposes of safety analysis. The term "general concept of defence-in-depth" when applied to nuclear power sources in outer space considers the use of design features and mission operations in place of or in addition to active systems, to prevent or mitigate the consequences of system malfunctions. Redundant safety systems are not necessarily required for each individual component to achieve this purpose. Given the special requirements of space use and of varied missions, no particular set of systems or features can be specified as essential to achieve this objective. For the purposes of paragraph 2.4 of principle 3, the term "made critical" does not include actions such as zero-power testing which are fundamental to ensuring system safety.

Principle 3. Guidelines and criteria for safe use

In order to minimize the quantity of radioactive material in space and the risks involved, the use of nuclear power sources in outer space shall be restricted to those space missions which cannot be operated by non-nuclear energy sources in a reasonable way.

1. General goals for radiation protection and nuclear safety

1.1 States launching space objects with nuclear power sources on board shall endeavour to protect individuals, populations and the biosphere against radiological hazards. The design and use of space objects with nuclear power sources on board shall ensure, with a high degree of confidence, that the hazards, in foreseeable operational or accidental circumstances, are kept below acceptable levels as defined in paragraphs 1.2 and 1.3.

Such design and use shall also ensure with high reliability that radioactive material does not cause a significant contamination of outer space.

1.2 During the normal operation of space objects with nuclear power sources on board, including re-entry from the sufficiently high orbit as defined in paragraph 2.2, the appropriate radiation protection objective for the public recommended by the International Commission on Radiological Protection shall be observed. During such normal operation there shall be no significant radiation exposure.

1.3 To limit exposure in accident%, the design and construction of the nuclear power source systems shall take into account relevant and generally accepted international radiological protection guidelines.

Except in cases of low-probability accidents with potentially serious radiological consequences, the design for the nuclear power source systems shall, with a high degree of confidence, restrict radiation exposure to a limited geographical region and to individuals to the principal limit of 1 mSv in a year. It is permissible to use a subsidiary dose limit of 5 mSv in a year for some years, provided that the average annual effective dose equivalent over a lifetime does not exceed the principal limit of 1 mSv in a year.

The probability of accidents with potentially serious radiological consequences referred to above shall be kept extremely small by virtue of the design of the system.

Future modifications of the guidelines referred to in this paragraph shall be applied as soon as practicable.

1.4 Systems important for safety shall be designed, constructed and operated in accordance with the general concept of defence-in-depth. Pursuant to this concept, foreseeable safety-related failures or malfunctions must be capable of being corrected or counteracted by an action or a procedure, possibly automatic.

The reliability of systems important for safety shall be ensured, *inter alia,* by redundancy, physical separation, functional isolation and adequate independence of their components.

Other measures shall also be taken to raise the level of safety.

2. Nuclear reactors

2.1 Nuclear reactors may be operated:

(i) On interplanetary missions;

(ii) In sufficiently high orbits as defined in paragraph 2.2;

(iii) In low-Earth orbits if they are stored in sufficiently high orbits after the operational part of their mission.

2.2 The sufficiently high orbit is one in which the orbital lifetime is long enough to allow for a sufficient decay of the fission products to approximately the activity of the actinides. The sufficiently high orbit must be such that the risks to existing and future outer space missions and of collision with other space objects are kept to a minimum. The necessity for the parts of a destroyed reactor also to attain the required decay time before re-entering the Earth's atmosphere shall be considered in determining the sufficiently high orbit altitude.

2.3 Nuclear reactors shall use only highly enriched uranium 235 as fuel. 'ne design shall take into account the radioactive decay of the fission and activation products.

2.4 Nuclear reactors shall not be made critical before they have reached their operating orbit or interplanetary trajectory.

2.5 The design and construction of the nuclear reactor shall ensure that it cannot become critical before reaching the operating orbit during all possible events, including rocket explosion, re-entry, impact on ground or water, submersion in water or water intruding into the core.

2.6 In order to reduce significantly the possibility of failures in satellites with nuclear reactors on board during operations in an orbit with a lifetime less than in the sufficiently high orbit (including operations for transfer into the sufficiently high orbit), there shall be a highly reliable operational system to ensure an effective and controlled disposal of the reactor.

3. **Radioisotope generators**

3.1 Radioisotope generators may be used for interplanetary missions and other missions leaving the gravity field of the Earth. They may also be used in Earth orbit if, after conclusion of the operational part of their mission, they are stored in a high orbit. In any case ultimate disposal is necessary.

3.2 Radioisotope generators shall be protected by a containment system that is designed and constructed to withstand the heat and aerodynamic forces of re-entry in the upper atmosphere under foreseeable orbital conditions, including highly elliptical or hyperbolic orbits where relevant. Upon impact, the containment system and the physical form of the isotope shall ensure that no radioactive material is scattered into the environment so that the impact area can be completely cleared of radioactivity by a recovery operation.

Principle 4. Safety assessment

1. A launching State as defined in principle 1A, paragraph 1, at the time of launch shall, prior to the launch, through cooperative arrangements, where relevant, with those which have designed, constructed, or manufactured the nuclear power sources, or will operate the space object, or from whose territory or facility such an object will be launched, ensure that a thorough and comprehensive safety assessment is conducted. This assessment shall cover as well all relevant phases of the mission and shall deal with all systems involved, including the means of launching, the space platform, the nuclear power sources and its equipment and the means of control and communication between ground and space.

2. This assessment shall respect the guidelines and criteria for safe use contained in principle 3.

3. Pursuant to article XI of the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies, the results of this safety assessment, together with, to the extent feasible, an indication of the approximate intended time frame of the launch, shall be made publicly available prior to each launch, and the Secretary-General of the United Nations shall be informed on how States may obtain such results of the safety assessment as soon as possible prior to each launch.

Principle 5. Notification of re-entry

1. Any State launching a space object with nuclear power sources on board shall timely inform States concerned in the event this space object is malfunctioning with a risk of reentry of radioactive materials to the Earth. The information shall be in accordance with the following format:

A. **System parameters**

A.1 Name of launching State or States including the address of the authority which may be contacted for additional information or assistance in case of accident

A.2 International designation

A.3 Date and territory or location of launch

A.4 Information required for best prediction of orbit lifetime, trajectory and impact region

A.5 General function of spacecraft

B. Information on the radiological risk of nuclear power source(s)

B. 1 Type of nuclear power source: radioisotopic/reactor

B.2 The probable physical form, amount and general radiological characteristics of the fuel and contaminated and/or activated components likely to reach the ground. The term "fuel" refers to the nuclear material used as the source of heat or power.

This information shall also be transmitted to the Secretary-General of the United Nations.

2. The information, in accordance with the format above, shall be provided by the launching State as soon as the malfunction has become known. It shall be updated as frequently as practicable and the frequency of dissemination of the updated information shall increase as the anticipated time of re-entry into the dense layers of the Earth's atmosphere approaches so that the international community will be informed of the situation and will have sufficient time to plan for any national response activities deemed necessary.

3. The updated information shall also be transmitted to the Secretary-General of the United Nations with the same frequency.

Principle 6. Consultations

States providing information in accordance with principle 5 shall, as far as reasonably practicable, respond promptly to requests for further information or consultations sought by other States.

Principle 7. Assistance to States

1. Upon the notification of an expected re-entry into the Earth's atmosphere of a space object containing a nuclear power source on board and its components, all States possessing space monitoring and tracking facilities, in the spirit of international cooperation, shall communicate the relevant information that they may have available on the malfunctioning space object with a nuclear power source on board to the Secretary-General of the United Nations and the State concerned as promptly as possible to allow States that might be affected to assess the situation and take any precautionary measures deemed necessary.

2. After re-entry into the Earth's atmosphere of a space object containing a nuclear power source on board and its components:

(a) The launching State shall promptly offer, and if requested by the affected State, provide promptly the necessary assistance to eliminate actual and possible harmful effects, including assistance to identify the location of the area of impact of the nuclear power source on the Earth's surface, to detect the re-entered material and to carry out retrieval or clean-up operations;

(b) All States, other than the launching State, with relevant technical capabilities and international organizations with such technical capabilities shall, to the extent possible, provide necessary assistance upon request by an affected State.

In providing the assistance in accordance with subparagraphs (a) and (b) above, the special needs of developing countries shall be taken into account.

Principle 8. Responsibility

In accordance with article VI of the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies, States shall bear international responsibility for national activities involving the use of nuclear power sources in outer space, whether such activities are carried on by governmental agencies or by nongovernmental entities, and for assuring that such national activities are carried out in conformity with that Treaty and the recommendations contained in these Principles. When activities in outer space involving the use of nuclear power sources are carried on by an international organization, responsibility for compliance with the aforesaid Treaty and the recommendations contained in these Principles shall be borne both by the international organization and by the States participating in it.

Principle 9. Liability and compensation

1. In accordance with article VII of the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies, and the provisions of the Convention on International Liability for Damage Caused by Space Objects, each State which launches or procures the launching of a space object and each State from whose territory or facility a space object is launched shall be internationally liable for damage caused by such space objects or their component parts. This fully applies to the case of such a space object carrying a nuclear power source on board. Whenever two or more States jointly launch such a space object, they shall be jointly and severally liable for any damage caused, in accordance with article V of the above-mentioned Convention.

2. The compensation that such States shall be liable to pay under the aforesaid Convention for damage shall be determined in accordance with international law and the principles of justice and equity, in order to provide such reparation in respect of the damage as will restore the person, natural or juridical, State or international organization on whose behalf a claim is presented to the condition which would have existed if the damage had not occurred.

3. For the purposes of this principle, compensation shall include reimbursement of the duly substantiated expenses for search, recovery and clean-up operations, including expenses for assistance received from third parties.

Principle 10. Settlement of disputes

Any dispute resulting from the application of these Principles shall be resolved through negotiations or other established procedures for the peaceful settlement of disputes, in accordance with the Charter of the United Nations.

Principle 11. Review and revision

These Principles shall be reopened for revision by the Committee on the Peaceful Uses of Outer Space no later than two years after their adoption.

Annex II: Summary of Space Radioisotope Power Systems Launched by the United States

Power Source	Spacecraft	Mission Type	Launch Date	Status
SNAP-3B7	Transit 4A	Navigational	29 Jun 1961	RTG operated for 15 years. Satellite now shutdown but operational.
SNAP-3B8	Transit 4B	Navigational	15 Nov 1961	RTG operated for 9 years. Satellite operation was intermittent after 1962 high altitude test. Last reported signal in 1971.
SNAP-9A	Transit 5-BN-1	Navigational	28 Sep 1963	RTG operated as planned. Non-RTG electrical problems on satellite caused satellite to fail after 9 months.
SNAP-9A	Transit 5-BN-2	Navigational	5 Dec 1963	RTG operated for over 6 yrs. Satellite lost navigational capability after 1.5 years.
SNAP-9A	Transit 5-BN-3	Navigational	21 Apr 1964	Mission was aborted because of launch vehicle failure. RTG burned up on reentry as designed.
SNAP-19B2	Nimbus-B-1	Meteorological	18 May 1968	Mission was aborted because of range safety destruct. RTG heat sources recovered and recycled.
SNAP-19B3	Nimbus III	Meteorological	14 Apr 1969	RTGs operated for over 2.5 years (no data taken after that).
ALRH	Apollo 11	Lunar Surface	14 Jul 1969	Radioisotope heater units for seismic experimental package. Station was shutdown Aug 3, 1969.
SNAP-27	Apollo 12	Lunar Surface	14 Nov 1969	RTG operated for about 8 years (until station was shutdown).
SNAP-27	Apollo 13	Lunar Surface	11 Apr 1970	Mission aborted on way to moon. Heat source returned to South Pacific Ocean.
SNAP-27	Apollo 14	Lunar Surface	31 Jan 1971	RTG operated for over 6.5 years (until station was shutdown).
SNAP-27	Apollo 15	Lunar Surface	26 Jul 1971	RTG operated for over 6 years (until station was shutdown).
SNAP-19	Pioneer 10	Planetary	2 Mar 1972	RTGs still operating. Spacecraft successfully operated to Jupiter and is now beyond orbit of Pluto.
SNAP-27	Apollo 16	Lunar Surface	16 Apr 1972	RTG operated for about 5.5 years (until station was shutdown).
Transit-RTG	"Transit"	Navigational	2 Sep 1972	RTG still operating. (Triad-01-1X)
SNAP-27	Apollo 17	Lunar Surface	7 Dec 1972	RTG operated for almost 5 years (until station was shutdown).
SNAP-19	Pioneer 11	Planetary	5 Apr 1973	RTGs still operating. Spacecraft successfully operated to Jupiter, Saturn, and beyond.
SNAP-19	Viking 1	Mars Surface	20 Aug 1975	RTGs operated for over 6 years (until lander was shutdown).
SNAP-19	Viking 2	Mars Surface	9 Sep 1975	RTGs operated for over 4 years until relay link was lost.
MHW-RTG	LES 8*	Communications	14 Mar 1976	RTGs still operating.
MHW-RTG	LES 9*	Communications	14 Mar 1976	RTGs still operating.
MHW-RTG	Voyager 2	Planetary	20 Aug 1977	RTGs still operating. Spacecraft successfully operated to Jupiter, Saturn, Uranus, Neptune, and beyond.
MHW-RTG	Voyager 1	Planetary	5 Sep 1977	RTGs still operating. Spacecraft successfully operated to Jupiter, Saturn, and beyond.
GPHS-RTG	Galileo	Planetary	18 Oct 1989	RTGs still operating. Spacecraft in route to Jupiter.
GPHS-RTG	Ulysses	Planetary/Solar	6 Oct 1990	RTG still operating. Spacecraft in route to Solar Polar fly-by.

* Single launch vehicle with double payload.

Source: M.S. El-Genk, ed., *A Critical Review of Space Nuclear Power and Propulsion 1984-1993*, (New-York: American Institute of Physics, 1994) 18.

Annex III: Summary of Space Nuclear Power Systems Launched by the United States (1961-1990)

Spacecraft Designation	Mission Type	Launch Date	Power Source (# Sources/Nominal Power)	Status
TRANSIT 4A	Navigation	29 Jun 61	SNAP[b]-3B7 (1/2.7W_e)	Successfully achieved orbit.
TRANSIT 4B	Navigation	15 Nov 61	SNAP-3B8 (1/2.7W_e)	Successfully achieved orbit.
TRANSIT 5BN-1	Navigation	28 Sep 63	SNAP-9A (1/25W_e)	Successfully achieved orbit.
TRANSIT 5BN-2	Navigation	5 Dec 63	SNAP-9A (1/25W_e)	Successfully achieved orbit.
TRANSIT 5BN-3	Navigation	21 Apr 64	SNAP-9A (1/25W_e)	Failed to achieve orbit; RTG burned up on reentry as designed.
SNAPSHOT	Experimental	3 Apr 65	SNAP-10A (1/500W_e)	Successfully achieved orbit; spacecraft voltage regulator malfunction after 43 days resulted in permanent reactor shutdown as designed. Reactor in 3000+ yr orbit.
NIMBUS B-1	Meteorological	18 May 68	SNAP-19B2 (2/40W_e ea)	Vehicle destroyed during launch; RTGs retrieved intact; fuel used on later mission.
NIMBUS III	Meteorological	14 Apr 69	SNAP-19B3 (2/40W_e ea)	Successfully achieved orbit.
APOLLO 12	Lunar Exploration	14 Nov 69	SNAP-27 (1/70W_e)	Successfully placed on Moon.
APOLLO 13	Lunar Exploration	11 Apr 70	SNAP-27 (1/70W_e)	Mission aborted en route to Moon; RTG survived reentry and sank in deep ocean.
APOLLO 14	Lunar Exploration	31 Jan 71	SNAP-27 (1/70W_e)	Successfully placed on Moon.
APOLLO 15	Lunar Exploration	26 Jul 71	SNAP-27 (1/70W_e)	Successfully placed on Moon.
PIONEER 10	Outer Solar System Exploration	2 Mar 72	SNAP-19 (4/40W_e ea)	Successfully placed on interplanetary trajectory.
APOLLO 16	Lunar Exploration	16 Mar 72	SNAP-27 (1/70W_e)	Successfully placed on Moon.
TRANSIT	Navigation	2 Sep 72	TRANSIT-RTG (1/30W_e)	Successfully achieved orbit.
APOLLO 17	Lunar Exploration	7 Dec 72	SNAP-27 (1/70W_e)	Successfully placed on Moon.
PIONEER 11	Outer Solar System Exploration	5 Apr 73	SNAP-19 (4/40W_e ea)	Successfully placed on interplanetary trajectory.
VIKING 1	Mars Exploration	20 Aug 75	SNAP-19 (2/40W_e ea)	Successfully placed on Mars.
VIKING 2	Mars Exploration	9 Sep 75	SNAP-19 (2/40W_e ea)	Successfully placed on Mars.
LES 8	Communications	14 Mar 76	MHW (2/150W_e ea)	Successfully achieved orbit.
LES 9	Communications	14 Mar 76	MHW (2/150W_e ea)	Successfully achieved orbit.
VOYAGER 2	Outer Solar System Exploration	20 Aug 77	MHW (3/150W_e ea)	Successfully placed on interplanetary trajectory.
VOYAGER 1	Outer Solar System Exploration	5 Sep 77	MHW (3/150W_e ea)	Successfully placed on interplanetary trajectory.
GALILEO	Jovian Exploration	18 Oct 89	GPHS-RTG (2/275W_e ea)	En route to explore Jupiter.
ULYSSES	Solar Polar Exploration	6 Oct 90	GPHS-RTG (1/275W_e)	Successfully placed in heliocentric orbit.

a Updated from Bennett (1987 and 1991)

b SNAP stands for Systems for Nuclear Auxiliary Power; odd-numbered SNAP systems are RTGs while even-numbered SNAP systems are nuclear reactors.

MHW Multi-Hundred Watt RTG

LES Lincoln Experimental Satellite

GPHS-RTG General Purpose Heat Source RTG

Source: M.S. El-Genk, ed., *A Critical Review of Space Nuclear Power and Propulsion 1984-1993*, (New-York: American Institute of Physics, 1994) 271.

Annex IV: Upcoming RTG Plutonium-Powered Launches

1. **Outer Solar System Missions**

- Comet Nucleus Mission; 2002 launch date (25.5 Kg. Pu-238)
- Pluto Flyby; 2003 launch date (25.5 Kg))

2. **Mars**

- MESUR: 3 launches planned in 1999, 2001, 2003 (total of 10.5 kg)
- Mars SR: 2 launches in 2007 and 2009 (total of 6.5 kg)

3. **Moon**

- Site Rover: launch in 1998 (13.5 kg)
- Telescope: Launch in 1999 (18 kg)
- Network: launches planned in 2001 and 2002 (total of 9 kg).

Source: Florida Coalition for Peace and Justice

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Agreement on the Rescue of Astronauts, the Return of Astronauts and the Return of Objects Launched into Outer Space, opened for signature at London, Moscow and Washington on 22 April 1968, entered into force on 3 December 1968, 672 U.N.T.S. 119; 19 U.S.T. 7570, T.I.A.S. 6599, (1968) 7 I.L.M. 151.

Agreement Governing the Activities of States on the Moon and Other Celestial Bodies, opened for signature at New York on 18 December 1979, entered into force on 11 July 1984, 1963 U.N.T.S. 3; (1979) 18 I.L.M. 1434.

Convention on Assistance in the Case of a Nuclear Accident (1986), adopted 24-26 September 1986, opened for signature at Vienna and at New York, entered into force on 26 February 1987, IAEA, 1986, INFCIRC/336 and Add.8, IAEA OR (1993), INFCIRC/336.Add.8.

Convention on Early Notification of a Nuclear Accident, adopted 24-26 September 1986, opened for signature at Vienna and at New York, entered into force on 27 October 1986, IAEA OR, 1986, INFCIRC/335.

Convention on International Liability for Damage caused by Space Objects, opened for signature at London, Moscow and Washington on 29 March 1972, entered into force on 1 September 1972, 961 U.N.T.S. 187; 24 U.S.T. 2389, I.I.A.S. 7762.

Convention on Registration of Objects Launched into Outer Space, adopted 14 January 1975, entered into force on 15 September 1976, 28:1 U.S.T. 695, T.I.A.S. 8480.

Declaration on the Human Environment, adopted by the United Conference on the Human Environment, Stockholm, 16 June 1972.

Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies, opened for signature at London, Moscow and Washington on 22 April 27 January 1967, entered into force on 10 October 1967, 610 U.N.T.S.205;18 U.S.T. 2410 T.I.A.S. 6347; (1967) 6 I.L. 386.

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