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THE UN COMMITTEE ON THE PEACEFUL USES OF OUTER SPACE: ADOPTION OF PRINCIPLES RELEVANT TO THE USE OF NUCLEAR POWER SOURCES IN OUTER SPACE+

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Abstract

On 26 June 1992 UNCOPUOS adopted "Principles Relevant to the Use of Nuclear Power Sources in Outer Space" by consensus. In December 1992 this set of Principles could be adopted unanimously by the UN General Assembly in its Resolution 47/68 of 14 December 1992 thereby obtaining universal acceptance. The importance of the adoption of this Resolution lies in the fact that for the first time the necessity to regulate the use of radioactivity in outer space has been explicitly recognized on an international level in a similar way as this necessity has been recognized for terrestrial application. This does not mean, of course, that the technical measures themselves stipulated in the regulations are likely to have any similarity, but their effects will have to ensure the same or an even more stringent level of protection for the general public. Although these Principles do not have the legally binding force of a convention, they do provide a useful guideline for the future development of nuclear power sources for use in outer space especially since the only nations which have used NPS in outer space yet namely the USA and the USSR have both been active in the negotiations (especially from the technical point of view) and the paragraph by paragraph adoption of the Principles. In addition to this all space nations which are capable of building nuclear power sources for the use in outer space were involved in the unanimous adoption of the Principles. Therefore the Principles might be considered as a pragmatic step towards the possible adoption of a convention in later years based on the experience gained by these Principles. The adoption will also give moral support to those scientists and engineers who feel the responsibility of advocating the restriction of the use of nuclear power in space to an absolute minimum under the most stringent safety measures.

In the following a short comment will be given to the Principles from the legal as well as from the scientific and technical point of view.

1. General[1]

On 26 June 1992 UNCOPUOS adopted "Principles Relevant to the Use of Nuclear Power Sources in Outer Space" by consensus. In December 1992 this set of Principles could be adopted unanimously by the UN General Assembly in its Resolution 47/68 of 14 December 1992 thereby obtaining universal acceptance. The importance of the adoption of this Resolution lies in the fact that for the first time the necessity to regulate the use of radioactivity in outer space has been explicitly recognized on an international level in a similar way as this necessity has been recognized for terrestrial application. This does not mean, of course, that the technical measures themselves stipulated in the regulations are likely to have any similarity, but their effects will have to ensure the same or an even

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more stringent level of protection for the general public. Although these Principles do not have the legally binding force of a convention, they do provide a useful guideline for the future development of nuclear power sources for use in outer space especially since the only nations which have used NPS in outer space yet namely the USA and the USSR have both been active in the negotiations (especially from the technical point of view) and the paragraph by paragraph adoption of the Principles. In addition to this all space nations which are capable of building nuclear power sources for the use in outer space were involved in the unanimous adoption of the Principles. Therefore the Principles might be considered as a pragmatic step towards the possible adoption of a convention in later years based on the experience gained by these Principles. The adoption will also give moral support to those scientists and engineers who feel the responsibility of advocating the restriction of the use of nuclear power in space to an absolute minimum under the most stringent safety measures.

In the following a short comment will be given to the Principles from the legal as well as from the scientific and technical point of view.

2. Scope

As to the general scope of the Principles the title addresses all types of nuclear power sources. However, as it will be explained further down, the Principles so far apply to power sources for electricity generation only. At least technical concepts if not laboratory proven prototyps exist also for nuclear heat sources for anticipated future use for propulsion purposes. Although they are generally intended for interplanetary flight, they are potentially hazardous during launch and "swing-by" trajectories around the earth. Unfortunately the occasion has been missed to include at least some good intentions applying to these nuclear power sources.

The last words of the title, namely "in outer space", might create the false impression given the vast dimensions of outer space that these Principles are of little practical concern down on earth. Although they apply everywhere in space, they are of practical importance especially to a comparatively thin layer of several hundred kilometres thickness around the earth. This is due to the fact that this layer between roughly 200 and 800 kilometres above the earth surface is that part of outer space from which interaction with the earth's biosphere is very likely and where most human space activities presently take place. This "inner layer" of outer space is about thirty to fifty times thicker than the biosphere, on the other hand it is equivalent to roughly one twentieth of the earth radius. Beyond this most important "inner layer" of outer space these Principles will in due course apply to any future lunar activity, which is then about sixty earth radia away from the earth. Even more remote but not negligible is the applicability of these Principles to the Mars region. In the "real" outer space beyond our solar system there seem to be no human interests to be protected by these Principles. On the other hand the accident of the Cosmos 954 satellite, which had triggered the discussion of these Principles, has shown drastically the impact nuclear space activities in near earth orbit can have on the general public on the earth surface. It is in this context where the real importance of the adoption of these Principles resides.

3. Preamble

The first paragraph of the preamble recognizes the fact that due to its extremely high energy density nuclear power is indispensible for certain missions. It is also true that nuclear power sources do have a very long life and are extremely reliable power generators due to the fact that they do not depend on moving parts or the sunlight. Under these circumstances it is not surprising that there will always be a number of missions that do require the presence of nuclear power sources onboard spacecraft and those cases are explicitly addressed by these Principles as noted in the second paragraph of the preamble.

Since this "inner layer" of outer space interacts with the biosphere and begins in a distance which would be described on earth as being two to three hours away by train or car and since satellites in many low earth orbits overfly most countries of the earth and not only once, but once per day, it seems obvious to recognize the fact, as it is done in article three of the preamble, that the use of radioactive power sources in that area should be subject to a thorough assessment of the risks to the general public living underneath. The preamble consequently recognizes this need and the formulation of Principles to this effect in its fourth paragraph.

The sixth paragraph of the preamble unfortunately limits the applicability of the Principles to nuclear power sources devoted to generation of electric power on board space objects for non-propulsive purposes and also to systems used and missions performed at the present time. This provides basically a number of loopholes for bypassing these Principles. It is a severe limitation of these Principles that they do not explicitly stipulate that at least the basic intention of the Principles should continue to apply for any additional future use of nuclear power in space as explained further down in the context of Principle 3. It has to be admitted though that nuclear propulsion systems are not yet operational (maybe they will never become operational for technical or financial reasons). This is especially true since nuclear propulsion is very likely to require power levels orders of magnitude higher

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than those implicitly referred to in these Principles. On the other hand one can consider the adoption of these Principles as setting a moral precedence for other applications of nuclear power in space.

The technical revision clause contained in the seventh paragraph of the preamble basically acknowledges the fact that these Principles do not intend to limit the development of new space power systems. As long as this development leads to increased safety, any limitation would indeed be counter-productive for these Principles. Against this background it is particularly deplorable that the preceeding paragraph is so severely limiting the applicability of these Principles with regard to nuclear propulsion systems. One can only hope that the next revision will lead to an expansion of the scope of these Principles.

Reference is made in the seventh paragraph of the preamble to international recommendations on radiological protection. Although this seems to be quite logical given the proximity of some space operations to the Earth surface, i.e. human habitation and the coverage of practically all countries on earth, the recognition of this fact in the Principles is a major breakthrough. This is even more so since everyone on earth runs a real, though statistically speaking highly improbable, risk without having a personal (like a medical x-ray) or collective (like nuclear generated electricity) benefit in return. Whilst many requirements placed on the design of nuclear reactors on earth do not apply to reactors in space for good technical reasons, there are absolutely no reasons why the guidelines for rules for radiological protection should not apply to any circumstances in which humans are affected by radioactivity stemming from space devices.

4. Use of terms

Sections 1 and 2 of Principle 2 deal with the term "launching State" which is a key term in international space law and extremely important here since the Principles impose a number of important and highly difficult obligations on the so called "launching State". Of course this term has already been dealt with in Article 1 (c) of the Convention on International Liability for Damage Caused by Space Objects and means:

"A State which launches or procures the launching of a space object and a State from whose territory or facility a space object is launched."

For the purpose of the NPS Principles however, this definition is only useful for Principle 9 namely with regard to liability and compensation (In that case all States which are launching States according to this definition are liable according to the norms of international space law for damage caused by space objects).

This definition of launching State however, is not useful with respect to the remaining Principles, especially to Principle 3, 4 and 5. The reason for this is that the obligations as contained in these Principles can reasonably not be imposed on all the launching States as described in Article 1 of the Liability Convention. As to Principle 3 for example the "launching State" is obliged to comply with general goals for radiation protection and nuclear safety as well as a number of safety measures etc. as explained under section 2.4 of this article below. These obligations can only be fulfilled by those States which have jurisdiction and control over the NPS. (This implies of course effective **control** under regular circumstances as well as in case of an accident when the NPS is "out of control"). Therefore it is useful to impose the obligations as contained in e.g. Principle 3 on the State which exercises jurisdiction and control over a space object with nuclear power sources on board. In this connection we have to keep in mind that the State which exercises jurisdiction and control during the use of the NPS in outer space might even change. For example: the US launch an NPS onboard their space shuttle and bring this NPS to the Italian section of the international space station. Then they hand the NPS over to an Italian astronaut and leave it to his full and exclusive disposition. In that case the US would take the full responsibility for compliance with Principle 3 until the point of time when the NPS is handed over to another nation. Then of course jurisdiction and control passes from the US to Italy and the US would not even be able to fulfill any obligations with respect to the NPS as contained in the Principles. This shows the reasons to impose the obligations as contained in the NPS Principles 3, 4, and 5 on the State which exercises jurisdiction and control over the NPS at a given point in time relevant to the Principle concerned. This is also particularly clear in a case when Principle 5 applies namely in the event that a space object with an NPS on board is malfunctioning with a risk of reentry of radioactive materials to the earth. In that case only that State can give the notifications and information as required in Priniciple 5 reliably that has jurisdiction and control and thereby the most technical information on the NPS.

It is for these reasons that sections 1 and 2 of Principle 2 were drafted: These sections distinguish between Principle 9 on the one hand and all other Principles where the term launching State is mentioned. As to Principle 9 the definition of the term launching State according to Article 1 of the Liability Convention is applicable (Principle 2 section 2 says "The term launching State as contained in that Principle is applicable". This refers exactly to Article 1 since in Principle 9 the definition as contained in Article 1 of

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the Liability Convention is simply repeated.) As to all other Principles where the term launching State is mentioned, this term refers to the State which exercises jurisdiction and control over a space object with NPS on board at a given point in time relevant to the particular Principle concerned.

Section 3 of Principle 2 describes a number of terms used in technical context in such a way that their implications become less ambiguous in legal terms. It limits the responsibility of the designer and the safety officer in the sense that he has to take into account and consider in his safety assessment only those malfunctions which are known to have occurred or which are likely to occur. However, the concept of "defence-in-depth" requires a series of technical provisions capable of counteracting a possible malfunction of the first or the second system required for safe operation of the nuclear power source. This section eliminates any residual ambiguity concerning reactor testing before launch as required for system safety testing.

5. Principle 3.

Guidelines and criteria for safe use

The introductory sentence of this Principle is of such universal character that it could apply without any negative effects to space propulsion as well. It is hard to understand why the occasion to adopt such universal guidelines was missed. As all further sections of this set of Principles show, the provisions of these Principles have to be adapted to each particular application and time of nuclear power source in space. It would have been preferable to state explicitly in these Principles that the particular requirements applied to nuclear propulsion cannot yet be formulated at the present state of technological development. This would have added credibility to the present set of Principles and the intention to adjust them to technological progress in nuclear space technology.

5.1 General goals for radiation protection and nuclear safety

These general goals apply first to the design and the intended use of space objects with nuclear power sources, and to their appropriate operation and finally to criteria to be met in case of accidents. Finally recommendations are made on the system level. No provisions are made for the case that humans will be on board of spacecraft having nuclear power sources on board. In this case it remains left to the astronaut and to his employer to accept or reject the risks involved. (One might alternatively argue that those national laws which are in force in the country which has jurisdiction and control over such a spacecraft will also apply in space.)

Section 1.(a) of Principle 3 requires that individuals, populations and the biosphere are to be protected against radiological hazards in operational and accidental circumstances. The design and the use of space objects is requested to ensure this with a high degree of confidence. Finally the design and use of such nuclear power source shall also avoid contamination of outer space which again means as described initially the "innermost shell" of outer space. These requirements are all encompassed and formulated in the appropriate language of probability.

Section 1.(b) of Principle 3 makes use of the vast experience and highly respected recommendations made by the International Commission on Radiological Protection. As individuals, populations and the biosphere are to be protected this was the most logical course of action to follow. It would not have been appropriate for the space experts to try to develop different radiological protection standards.

Section 1.(c) refers to the generally accepted international radiological protection guidelines. However, as the recommendations of the International Commission for Radiological Protection (ICRP) are not formulated with space in mind, reference is made to the more general radiological protection guidelines contained in these recommendations. The only logical limit in precise figures to be given in this context is the maximum permissible radiation dose for humans per year, which is 1 mSv per year. It is left to the designers and operators of space craft to ensure to the best of their ability that nobody on this earth will receive a higher radiation dose stemming from nuclear power sources to be used in space than permitted, regardless of how closely and how long he or she gets in contact with them. What that means in practice will be explained further down in the context of section 2.(f) of Principle 3. The value of 1 mSv per year is the one that applies to terrestrial application of nuclear power sources to everyone not concerned with the power source professionally or in case of rescue. If nuclear power sources for space applications are designed and operated with a high degree of confidence of an extremely low risk of accidents then one can accept the remaining risk as being less than equal to the risk incurred by everyone due to terrestrial application of nuclear power. This paragraph also states that any modification of the guidelines issued by the radiation experts shall apply as soon as practicable to these Principles. This is really all the general public can hope for.

According to point 1.(d) the principle of defence-in-depth is required on the system level.

This means that if the first safety mechanism fails, a second and third mechanism possibly of different nature shall ensure that malfunctions are excluded, stopped, compensated or counteracted by all technical

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means usually applied under these circumstances. In addition, this paragraph gives examples how the reliability of the safety sytems can be ensured. Any potential user of radioactive power sources in space who will be unable to prove in case of an accident which safety measures he has taken of the kind recommended here will be in definite violation of these Principles.

5.2 Nuclear reactors

After the description of general goals for radiation protection and nuclear safety, Principle 3 gives guidelines for the nuclear reactors on one hand and radioisotope generators on the other hand due to their different physical characteristics and operational processes involved. Nuclear reactors are treated first. They tend to be higher in power level as compared to the radioisotope generators. (In 1978 there was a spectacular accident with a nuclear generator onboard Cosmos 954 reentering from space and crashing on north Canadian territory.) Two of the six paragraphs devoted to nuclear reactors give design guidelines thus leaving the greatest amount of flexibility to engineers for improved future designs. Paragraph 2.(c) specifies the fuel to be used which is highly enriched uranium 235. Its fission products are the least dangerous ones as compared to other nuclear fuels. This requirement is unusually specific in this context and is intended to ban experimentation with other (potenially cheaper and more dangerous) nuclear fuels. This unanimous opinion of the technical experts should be taken very seriously.

Section 2.(e) enumerates the most important safety criteria such a reactor has to meet. They address very specifically a number of failure modes that are conceivable during operation especially launch of such a reactor. The stipulation that the reactor shall not become critical before reaching the operating orbit shall not exclude (as mentioned in Principle 2, section 3) that the reactor may be tested under zero power condition before launch. The four other paragraphs deal with operation of nuclear reactors. The first one specifies the kinds of missions for which nuclear reactors may be employed. These are interplanetary missions, sufficiently high orbits and as an exception also in low orbits, provided the reactors will be stored later in sufficiently high orbits. The next paragraph defines the term "sufficiently high orbit" and specifies conditions to be met for operating a nuclear reactor in such orbits rather than specifying a certain height for such an orbit. The reason is that a conservative value for a minimum height in kilometers or miles judged to be "sufficient" under any circumstances and for all possible design characteristics would have had to be based on so many worst case assumptions, that the costs involved in reaching that height were very likely to be unjustified. Therefore, the designer and operator of a nuclear power source was given the freedom and the responsibility to determine the sufficient height based on the individual parameters of his own design. To this end section 2.(b) specifies four conditions to be met by each individual space object with NPS on board: 1) it must remain long enough in orbit to allow for the decay of the fission products to given activity level, namely that of chemical elements called the actinides; 2) it must be of minimum danger to existing or future outer space missions; 3) it must bear a minimum risk of collision with other space objects; 4) these conditions have to be also met by parts of a reactor destroyed (by accident, collision or intention) in space. From these conditions it is obvious, that the height of a "sufficiently high" orbit will depend inter alia on the number and orbital parameters of the space objects to be launched in the future. It highlights the enormous burden of responsibility placed on those States intending to launch a space object with NPS on board.

Paragraph 2.(d) is a specific requirement concerning the operation of the reactor itself. It requests that the reactor shall not be made critical before it has reached its operating orbit or interplanetary trajectory. This is an important safety measure typical for nuclear devices. As stated in Principle 2 paragraph 3 this stipulation does not exclude the possibility to test the reactor under zero power level before launch which in itself is a safety measure again.

Section 2.(f) singles out one of the most important safety measures which make up the general concept of defence-in-depth. It requires the presence on board of highly reliable operational systems ensuring an effective and controlled disposal of the reactor in case it has not reached the sufficiently high orbit.

The high degree of flexibility left to the designers and operators of nuclear reactors is compensated by the extremely stiff requirement of the low final activity permitted and especially the limit of the maximum radiation dose of 1 mSv in a year specified in section 1.(c) that any individual on the earth may receive due to the function or malfunction of such nuclear reactors. This radiation dose level of 1 mSv in a year is so low, that it practically excludes operating nuclear reactors in low earth orbits as (theoretically) permitted in section 2.(a), item iii, since accidents between launch and reaching the sufficiently high orbit can never be excluded with absolute certainty, perhaps not even with an acceptably low probability, since also the safety measures stipulated in section 2.(f) could possibly fail. The burden of responsibility for the designer is likely to be higher and the burden of proof for any potential victim is likely to be lower by specifying the maximum tolerable consequences rather than specifying any design figures. At the same time it safeguards trade secrets normally important to the designers of such systems.

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With respect to radioisotope generators the first paragraph deals with the missions for which such power sources are permitted. Due to the inherent danger of these power sources it must be made sure that the radioisotope generator will never come back to the earth unless by controlled retrieval and proper disposal. The second and last paragraph lists the specific design requirements for such power sources. Again this article singles out the most critical failure modes and stipulates that the design must guarantee that this power source withstands the physical forces involved in such circumstances without being destroyed. Of course the same maximum permissible dose level of 1 mSv in a year applies also to anyone affected by any re-entry of such a radioisotope generator.

6. Safety Assessment

The preceding Principles do realistically not exclude the possibility of a malfunction. Very specifically it is their purpose to reduce the risk of any severe consequences of such malfunctions to a minimum. Consequently a safety assessment before launch is an essential requirement to ensure that the designers have really made a responsible choice taking into account up-to-date knowledge and experience. Furthermore such a safety assessment is a confidence building measure in the sense that such an assessment has also the function of a registration of a nuclear power source. This enables the general public to obtain reliable information on the question how many nuclear power sources are used in outer space and to draw their own conclusions on their own safety. Since during the negotiation of the NPS Principles it was impossible to agree on a Principle on notification of a nuclear power source according to the provisions of the Convention on Registration of Objects Launched into Outer Space the solution as contained in Principle 5 is possibly a useful compromise. According to Principle 4 it is the obligation of the "launching State" in cooperation with those which have designed, constructed or manufactured the nuclear power source or will operate the space object or from whose territory or facility such an object will be launched to furnish such a safety assessment. In this connection it might be interesting to mention that during the negotiations the term "launching State" was much disputed in spite of the definition of Principle 1 section 1 which says that the launching State in this connection means the State exercising jurisdiction and control over a space object. Developing countries who are interested in the possibility of launching space objects with NPS on board belonging to other States from their own launching sites were of the opinion that their country could never be a "launching State" according to Principle 5 since they would never have jurisdiction and control over the space object. Since the State that intended to launch the NPS from their territory would not even allow them to handle the NPS. Therefore they felt that they would never be responsible in the first place for the safety assessment since they did not even have knowledge about the construction of this item. As a contrary position the French delegation argued that only the State from whose territory a NPS was launched could be the "launching State" according to Principle 4 since they would be the only ones to have jurisdiction over the NPS as well as control in the sense that they would be the only State who could definitively give "the green light" for the launching and who had the full and exclusive "port authority" on their launching site. According to this conception the obligations of Principle 4 were regarded as a severe punishment to those States who allowed nuclear power sources to be launched from their territory without having the full knowledge required for its safety assessments about the NPS. During informal negotiations it could be heard from the American side that according to US law the United States would always claim full jurisdiction and control in case that they should launch an NPS from foreign territory. This point of view was shared by quite a number of other Western States. Section 1 of Principle 4 acknowledges explicitly the fact that the launch and the safe operation of a space object is usually a complex technical operation requiring the reliable joint performance of numerous technical systems frequently not provided for by or physically located in one single State. Consequently a thorough and complete safety assessment will require the cooperation of all experts in charge of the various systems i.e. also of all States involved. Section 1 addresses apart from the nuclear power source itself in particular the means for launching, i.e. the launch vehicle and the launch facility including its associated equipment, the space platform, i.e. the satellite, space probe, space station or similar unmanned space platforms, the systems onboard this platform relevant to the reliable functioning and safe operation of the NPS and the control and communication links between the operators on ground and the space object. As owners, designers and operators of all these systems have to cooperate in order to be able to establish a comprehensive safety assessment as required by these Principles section 1 of Principle 4 requires the launching State to conclude, prior, i.e. a long time before launch cooperative agreements with those States in possession of the information and technical expertise necessary. This information is usually a subset or component forming part of the complete safety assessment, which requires intimate knowledge of the design, construction, manufacturing, operation and testing of the system or facility involved and this system's or facility's direct or indirect interaction with the NPS. As this knowledge is usually confidential it is important that section 1 of Principle 4 does not require disclosure of detailed information but it requires cooperation in the preparation of the comprehensive safety assessment. This means in practice that States

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other than the launching State have to establish an agreed procedure with regard to this cooperation. The launching State, possibly assisted by other States, will then have to integrate these contributions to the comprehensive safety assessment. Such a safety cooperation avoids disclosure of detailed technical data to other States as such since it is sufficient to only communicate the conclusions drawn from the data by the own experts.

Principle 4 describes the essential features of the safety assessment required and stipulates that such safety assessment is made prior to launch and that all phases of a mission and the influences of all systems involved be taken into account. In this context paragraph 2 makes explicit reference to the guidelines and the criteria contained in Principle 3. As the safety assessment is one key element which ensures the practicability of these Principles, section 3 of Principle 4 makes explicit reference to Article 11 of the Treaty Governing the Activities of States in the Exploration and the Use of Outer Space and requires that the **result** of the safety assessment shall be made publicly available prior to the launch.

It is important to note that only the result of, not the safety assessment in its entirety, has to be made available, and that this has to take place prior to the launch of the NPS. The complete safety assessment, if it is as comprehensive as stipulated by these Principles, is quite likely to be very voluminous. It might easily consist of a number of files of several hundred pages as well as of several volumes of supporting documentation and references. Making all this material publicly available without restriction would neither be very practicable nor very useful for the ends of these Principles and would disclose proprietary information. Its preparation, however, is necessary in order to arrive at credible results, which could be a kind of summary of all this material, presented in a comprehensive form so that people possessing general knowledge in space technologies can understand it without having to consult experts or statistical charts etc.. It is these results which have to be made publicly available. Since they have to be available prior to the launch of an NPS their preparation might have to begin more than one year before. If international cooperative agreements have to be concluded for this purpose it is not unrealistic to assume that negotiations for such agreements will have to begin about three years before launch. If several similar space objects with NPS will be launched in succession, safety assessments will have to be established for each one of them but the time required will of course be much less for any follow-on launch. In each case the Secretary-General of the United Nations shall be informed on how States may obtain the results of such safety assessments. The Secretary-General himself is not involved in their actual distribution. This implies that a State intending to launch a nuclear power source informs the Secretary General about this intention so that he can forward this information to inquiring States. As there are a number of orbits on which satellites will overfly the vast majority of the States on earth it seems absolutely justified to entitle every UN-memberstate to request information on the safety assessment if nuclear power sources are used on a mission. Nobody would be able to bear the responsibility to limit the number of States entitled to this information given the large number of malfunctions possible.

7. Notification of re-entry

It is the existence of this Principle in itself which already represents quite a progress. Here the States have agreed, in the interest of a possible victim, to notify each other in case any space object with NPS onboard experiences difficulties, rather than trying to hide it for as long as possible, possibly hoping that nobody else discovers it or any resulting damage can be proven their fault. On the other hand one could see the acceptance of this Principle as an indication that there is a real possibility of danger, even if statistically very small. Perhaps too many face-saving attempts have already failed in the past. It is again the launching State referred to in Principle 2 who has to take the initiative in case of a malfunctioning which may involve radioactive material returning to the earth and notify the States concerned. "Concerned" is any State whose territory and perhaps atmosphere might be affected by the possibly reentering radioactive material. In order to be able to obtain at least a vague idea which States this could be and what kind of danger they might have to face, some minimum details of the information to be provided are specified in Principle 5. They are divided into groups namely of system parameters concerning the space object in general and those indicating the radiological characteristics of the NPS itself. The problem connected with the system parameters is contained in section A.(iv), according to which "information required for best prediction of orbit lifetime, trajectory and impact prediction" shall be given. This definition is not very precise and it is not even sure that all conceivable launching States will be able to determine these parameters with sufficient speed and accuracy and will be prepared to provide so important parameters as the ballistic coefficient of the space object in order to be useful. Consequently this matter is further dealt with in Principle 7 as discussed further down. The radiological characteristics listed in Principle 5 also represent a bare minimum. The "probable physical form...of the fuel" may not include fuel element chemical composition, particle size and the like. Also the <u>mass</u> of the reactor block or its components likely to reenter the atmosphere, if applicable, would be very valuable information. Given this the likeliness of a burn up before impact on the earth surface could be assessed. To some extent Principle 6 on consultation could compensate these short-

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comings if the States providing information do actually respond positively to the request for more information. In any case there is now at least a certain standard of information to be provided which is obvious and to be acknowledged.

A word of caution in order to avoid false expectations: Even if all information of the above mentioned type was available on time and processed to the limits of the present state of the art of re-entry prediction one would never be able to predict an impact "point". The best prediction even one hour before impact would be an area some thousand kilometers long and roughly one thousand kilometers wide. Mainly the ever changing parameters of the earth's upper atmosphere and the impossibility to predict the aerodynamic characteristics of the reentering part of unknown geometric form are responsible for this. The practical value of all this information lies in the chance that a large number of States do not unnecessarily have to take measures in order to prevent consequences e.g. in case of an impact on their territory.

In this context the updating of the information furnished is of great importance and consequently specifically taken into consideration in section 2 of Principle 5. In order to provide for reliable communication the Secretary-General of the United Nations shall be informed in the same way as the States concerned, so that any State not having received the information still has direct access to it.

8. Principle 7 (Assistance to States)

As already mentioned in the context of Principle 5 not all States which may possibly become launching States in the sense of Principle 2 will be able to determine the orbital parameters with optimum precision and speed. The technical installations and the constant operational readiness required represent a major capital investment and operating expense which only one or two States with large space budgets are able to afford. Especially for keeping track of space objects that have broken into several pieces or fail to emit beacon signals or to respond otherwise to signals emitted from ground stations this comes true. For the purposes of these Principles it is sufficient if "redundant", i.e. a minimum of two independent sets of installations are available provided they cover a large portion of the globe each. For other reasons a number of less complete and powerful installations will always exist which will in many cases be able to furnish valuable additional information. It is against this background that Principle 7 requires all States to pool their knowledge on a malfunctioning space object with a nuclear power source on board in case of an unexpected re-entry into the earth's atmosphere. To this end they are requested to inform the Secretary-General of the United Nations and the States concerned as promptly as possible.

Section 2 of Principle 7 deals with a different kind of assistance after re-entry of a nuclear power source into the earth's atmosphere.

The launching State has to offer its assistance to the affected State and is obliged, if the affected State requests it, to assist in limiting or eliminating all harmful effects which have occurred, including the detection of the affected area, retrieval of radioactive material and clean-up. All other States than the launching State and international organizations with relevant technical capabilities shall also provide assistance upon request of the affected State, but they are not required to take the initiative in offering their help. At the end of this section Principle 7 stipulates that assisting States and international organizations shall take into account special needs developing countries may have in such circumstances.

9. Principle 8 (Responsibility) and Principle 9 (Liability and Compensation)

From a purely theoretical point of view Principles 8 and 9 are possibly not spectacular to international lawyers since Principle 8 "only" restates State responsibility in accordance with international space law for national activities in outer space. In this connection the use of nuclear power sources is included in the responsibility for national activities.

As to Principle 9 the liability regime as contained in the Outer Space Treaty and the Liability Convention is restated which might possibly be regarded as superfluous by some theoreticians. However, it has to be pointed out in this connection that it is quite unusual in UN Resolutions, which do not have the status of a convention or international agreement, to mention State responsibility or liability at all. Especially in resolutions relating to environmental questions State responsibility and liability are not referred to and even in international agreements or conventions a trend can be observed to delete these questions. (For example: The Convention on Early Notification of a Nuclear Accident and the Convention on Assistance in Case of a Nuclear Accident or Radiological Emergency, both done on September 26, 1986, which were elaborated immediately after the Tschernobyl accident, do not even mention the terms responsibility, liability or compensation[2]) Therefore it is extremely important for the evaluation of the NPS Principles which at least for the time being have "only" the status of a unanimously adopted UN Resolution that the States involved in the negotiations namely all space nations as well as developing countries involved in space activities stressed the importance of the Principles as well as the seriousness of their intentions by elaborating Principles on State responsibility as well as liability and compensation.

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As to State liability it is interesting to mention that Principle 9 section 3 gives a specific interpretation to the term "damage" as contained in Article 1 of the Liability Convention since this term includes, according to the above mentioned Principle, reimbursement of the duely substantiated for search, recovery and clean-up-operations including expenses for assistance received from third parties. This implies that in case of an accident, States on whose territories damage occurs have the free choice among those States who offer their assistance for clean-up etc. The background for this paragraph is the following: When Cosmos 954 disintegrated over Canadian territory the Canadian Government accepted the help of the United States for search, recovery and clean-up-operations and asked the USSR for reimbursement of the expenses. The USSR, however, refused payment since they claimed that Canada had not been entitled to ask the United States for help since the USSR had already offered such help by their own experts who have vast knowledge about the type of the malfunctioning nuclear power source etc. Therefore the Sovietunion argued that it would have been much cheaper if the help of such Soviet experts had been accepted and the compensation to Canada would have been significantly lower if the Canadians would not have asked for help by the United States.

Therefore according to Principle 9 Section 3 the States on whose territory an NPS accident happens are free to choose among the States who offer their help. Nevertheless they can reimburse the full expenses for such action from the launching State.

10. Principle 11 (Review and Revision)

According to Principle 11 the period after which review and revision of the Principles have to be taken up is extremely short since the mentioned period of two years is within the United Nations almost synonymous to an immediate revision. The reason for this formulation is that UNCOPUOS recognizes the fast technological development in this area. Therefore it was unanimously accepted that it is not enough to elaborate a set of Principles on the use of nuclear power sources within more than a decade but it is necessary to keep up with new developments and publications. In this connection we have to bear in mind that nuclear propulsion systems which have not been included in the scope of application of these Principles are being developed and are likely to be tested or used e.g. for interplanetary missions in a couple of years unless tightening of space budgets will again slow down this devepolment. The adaption of these Principles and the inclusion of nuclear propulsion is absolutely necessary since nuclear propulsion systems will obviously have to be launched from the earth before they are "ignited" on their trajectory away from earth. Additional Principles have to be elaborated which govern or exclude their use in near earth regions. Much money can be saved or devoted to more promising projects if the Principles for the use of nuclear propulsion are known as early as possible. Therefore it is to be expected that NPS will remain a permanent item to be dealt with by UNCOPUOS even after the adoption of the Principles.

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ANNEX

UN Resolution 47/68 of 14 December 1992

PRINCIPLES RELEVANT TO THE USE OF NUCLEAR POWER SOURCES IN OUTER SPACE

Preamble

The General Assembly,

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,

Recognizing 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 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 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 the 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 Priniciples 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 excercises jurisdiction and control over a space object 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 purpose 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 only 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 .

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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 reentry 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 accidents, 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 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. The 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

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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 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 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 source 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 risk of re-entry of radioactive materials to the Earth. This 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 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 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

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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 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 non-governmental entitites, 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 organisation 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.

1 As to the factual and technical background of the negotiations see: Aftergood, Steven, Towards a Ban on Nuclear Power in Earth Orbit, Space Policy 25 (1989). Benkö/deGraaff/Reijnen, Space Law in the United Nations, Dordrecht 49 (1985). Benkö, Marietta, Nuklearenergie im Weltraum, in: Böckstiegel, K.-H. (Ed.), Handbuch des Weltraumrechts 457(1991).

2 Reprinted in: Böckstiegel, Karl Heinz/Benkö,Marietta, Space Law: Basic Legal Documents Vol I/Binder 1/1, B.III.3 and B.III.4.