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Summary of the U.S. Ad-Hoc Working Group Meeting on Revising the U.N. Principles on the Use of Nuclear Power Sources in Outer Space

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Background

- The United Nations began discussing the use of nuclear power sources (NPS) in outer space following the 1978 reentry of the Soviet reactor-powered satellite Cosmos 954 over Canada. The principal U.N. forums for discussions on the use of NPS in outer space have been the Committee on the Peaceful Uses of Outer Space (COPUOS), its two standing committees of the whole--the Legal Subcommittee (LSC) and the Scientific and Technical Subcommittee (STSC)--and special working groups established within the subcommittees to deal with this topic.

- The first technical consensus on the technical and scientific aspects relating to the use of NPS in space was achieved in 1981 by the STSC Working Group on the Use of Nuclear Power Sources in Outer Space. For various reasons this consensus was broken in the Legal Subcommittee leading to nine more years of discussions until a new "consensus" was reached in 1990. Within the U.S., technical experts found many flaws and inconsistencies with the 1990 principles. Some corrections were made before the U.N. General Assembly adopted the principles in 1992. This presentation summarizes the results of an ad-hoc meeting of U.S. technical experts held in 1991 to develop corrective language.

Background
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- Representatives from the U.S. Department of Energy (DOE), the U. S. Department of Defense (DoD), and the National Aeronautics and Space Administration (NASA) attended along with people from various government laboratories and contractors.

- The operational procedure used in the meeting was to focus on the "hard points", that is, the most technically inaccurate of the language in the U.N. draft Principle 3 ("Guidelines and criteria for safe use"). Each proposed change had to be defended as an essential change or it was not adopted. Thus, only a very small number of changes were made even though many of the attendees thought the entire set of 11 principles should be rewritten to be technically accurate and consistent.

- The revisions adopted by the Ad-Hoc Working Group were taken back to DOE, DoD, and NASA Headquarters for further action. Many of these changes found their way into the final text of the U.N. Principles as adopted by the U.N. General Assembly in 1992.

Principle 3: Guidelines and Criteria for Safe Use

Preamble

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.

Working Group Proposed Revisions

In order to enhance the safety of nuclear power sources (NPS), which include nuclear reactors and radioisotope power sources used for space power or propulsion, the decision to use NPS should be based on the technical merits with due consideration for safety and environmental aspects.

Summary of Reasons for the Proposed Revisions

The proposed new preamble puts the safety goal in a positive vein, that is, enhancing safety and environmental protection. The revision is also consisistent with the 1981 U.N. Working Group report which said that the decision to use nuclear power sources in outer space should be a technical one (all other factors equal). The U.S. has also noted that it is incongruous for one principle to have its own preamble.

Principle 3. Guidelines and Criteria for Safe Use
Section 1. General Goals for Radiation Protection and Nuclear Safety

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

Working Group Proposed Revisions

States launching space objects with nuclear power sources on board should endeavour to protect individuals, populations and the biosphere against radiological hazards. The design and use of space objects with nuclear power sources on board should ensure, with a high degree of confidence, that the risks in [DELETION] operational or accidental circumstances, are kept as low as reasonably achievable (ALARA).

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

Summary of Reasons for the Proposed Revisions

- **"Risks" has a quantitative definition (probability x consequences).**
- **"Foreseeable" encompasses everything (including the incredible).**
- **There are no dose limits for accidents.**

Section 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 (b), 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.

Working Group Proposed Revisions

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

Summary of Reasons for the Proposed Revisions

- The clarifying phrase "to the public" makes it clear that the ICRP standards apply only to the general public and then only in normal operation situations. The ICRP has no rigid standards for accidents because accidents are almost by definition events that are out of control.

Section 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.

Working Group Proposed Revisions

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

[DELETION OF DOSE LIMITS]

The probability of accidents with potentially serious radiological consequences [DELETION] should be kept extremely small by virtue of the design of the system. Future modifications of the guidelines referred to in this paragraph should be applied as soon as practicable.

Summary of Reason(s) for the Proposed Revisions

- There are no official dose limits for accidents just as there are no regulations restricting injuries or fatalities in automobile or airplane crashes.

Principle 3: Guidelines and Criteria for Safe Use
Section 1. General Goals for Radiation Protection and Nuclear Safety

Section 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.

Working Group Proposed Revisions

Systems important for safety should be designed, constructed and operated in accordance with the general concept of defence-in-depth for aerospace systems. Pursuant to this concept, credible safety-related failures or malfunctions should be [DELETION] corrected by design or counteracted by an action or a procedure, possibly automatic.
The reliabiility of systems important for safety should be ensured by consideration of redundancy, physical separation, functional isolation and adequate independence of their components.
Other measures may also be taken to raise the level of safety.

Summary of Reasons for the Proposed Revisions

- "Defence-in-depth" is a terrestrial reactor concept not appropriate to space NPS.
- RTGs have passive safety features hence the change to "corrected by design".
- The other changes (e.g., "must" to "should", "inter alia" to "consideration of" and "shall" to "may") basically make the paragraph more realistic.

Section 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.

Working Group Proposed Revisions

Nuclear reactors may be operated:
(i) On interplanetary missions;
(ii) In sufficiently high orbits (SHO) as defined in paragraph 2.2;
(iii) In any orbit or flight trajectory if they are stored in sufficiently high orbits after the operational part of their mission.

Summary of Reason(s) for the Proposed Revision

- The change from "in low Earth orbits" to "in any orbit or flight trajectory" allows the use of other than low-Earth orbit and also allows for nuclear propulsion missions which may need to use a "flight trajectory" rather than an "orbit".

Section 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.

Working Group Proposed Revisions

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 selection of the SHO should take into consideration the risks to existing and future outer space missions and [DELETION] collision with other space objects [DELETION]. The necessity for the parts of a destroyed reactor also to attain the required decay time before re-entering the Earth's atmosphere should be considered in determing the SHO altitude.

Summary of Reason(s) for the Proposed Revisions

To provide the mission planners with sufficient flexibility to meet the overall safety goals while still requiring consideration of orbital debris.

Section 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.

Working Group Proposed Revisions

Nuclear reactors should use only highly enriched uranium 235 as fuel. The design should take into account the radioactive decay of the fission and activation products.

Summary of Reasons for the Proposed Revisions

To give some flexibility in the choice of nuclear fuel. As an example, Section 2.3 excludes low-enriched uranium 235 which is not a problem. For certain futuristic mission scenarios other fissionable materials might be desirable.

Section 2.4

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

Working Group Proposed Revisions

Nuclear reactors should not be operated at power, except for zero-power testing before they have reached their operating orbit or [Deletion] trajectory.

Summary of the Reasons for the Proposed Revisions

- The revision allows zero-power testing before launch to ensure that the reactor is operational. Zero-power testing is a means of checking to ensure that the reactor systems work while operating at such a low ("zero") power that there is very little fission product buildup. If zero-power testing is not allowed the paradoxical result could be an even less safe system because in some mission scenarios the reactor is used to boost the satellite to a sufficiently high orbit (via some form of nuclear propulsion) so if the reactor did not operate because of the failure to perform preflight zero-power checkout tests then the sufficiently high orbit could not be reached.
- Deletion of "interplanetary" allows other safe trajectories or orbits to be used (e.g., heliocentric or lunar orbits).

Section 2.5

The design and construction of the nuclear reactor shall ensure that it can not 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.

Working Group Proposed Revisions

The design and construction of the nuclear reactor should ensure that it cannot become critical before reaching the operating orbit or flight trajectory considering credible launch accidents, including rocket explosion, inadvertent re-entry, impact on ground or water, submersion in water or water intruding into the core.

Summary of Reasons for the Proposed Revisions

- As originally written, the U.N. principles would have applied to nuclear propulsion systems as well. Thus, changing to "flight trajectory" acknowledges that nuclear propulsion systems may operate in other than an orbit and still be safe.
- The word "credible" limits the safety analyses to believable events and not "all possible events" which encompasses almost any thing anyone can think of no matter how far-fetched.
- The addition of the word "inadvertent" clarifies that the intent of this section is to deal with accidents.

Section 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.

Working Group Proposed Revisions

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 should be a highly reliable operational system to ensure an effective and controlled disposal of the reactor.

Summary of Reasons for the Proposed Revisions

In keeping with the objective of minimizing changes, the Ad-Hoc Working Group made no changes to this section (paragraph) except for replacing the word "shall" with the word "should" in keeping with the insistence of the U.S. delegations that the principles are non-binding and recommendatory only so the word "shall" is inappropriate.

Section 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.

Working Group Proposed Revisions

In keeping with the objective of minimizing changes, the Ad-Hoc Working Group made no changes to this section (paragraph). Some of the attendees at the Ad-Hoc Working Group Meeting noted that the term "ultimate disposal" was not defined and so could mean anything, including leaving the nuclear power source in orbit.

Section 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.

Working Group Proposed Revisions

Radioisotope generators should 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 credible orbital conditions, including highly elliptical or hyperbolic orbits where relevant. Upon impact, the containment system and the physical form of the isotope should minimize radioactive material release into the environment so that the debris can be retrieved.

Summary of the Reasons for the Proposed Revisions

- The word "foreseeable" was replaced with the word "credible" to focus on the believable events and not all foreseeable events which could include some far-out possibilities.
- The Working Group recognized that absolute containment cannot be guaranteed in all "foreseeable" accidents so it used words to give the designers some flexibility to minimize the consequences of postulated accidents while preserving the overall safety goals. The U.N. requirement is akin to requiring absolute protection of all passengers in an airplane crash.

Consequences of the Ad-Hoc Working Group Meeting

- As a result of the meeting of the Ad-Hoc Working Group the knowledgeable technical experts in the U.S. Government became united around a specific document which allowed them to press their respective policy organizations to argue for the necessary changes to make Principle 3 technically realistic and meaningful. Following the meeting on 8 January 1991, the U.S. delegation insisted on a number of changes to the overall principles. Since other delegations did not want to change Principle 3, the U.S.-led changes were made in other paragraphs, primarily in the Preamble to the overall principles and to Principle 2 ("Use of terms").

- In a number of formal statements, the U.S. has stated its view that the principles are non-binding and recommendatory only and that the words "shall" and "must" should be replaced by the word "should". The U.S. delegation has also taken exception to rigid dose limits applied to any accident.

- During the final U.N. adoption process in 1992, the U.S. expressed its reservations and interpretation in this statment: "The United States did not block the consensus recommendation of the Committee to forward the principles to the General Assembly, nor will the United States oppose their adoption here. On some points, however, it remains our view that the principles related to safe use of nuclear power sources in outer space do not yet contain the clarity and technical validity appropriate to guide the safe use of nuclear power sources in outer space. The United States has an approach on these points which it considers to be technically clearer and more valid and has a history of demonstrated safe and successful application of nuclear power sources. We will continue to apply that approach."

Consequences of the Ad-Hoc Working Group Meeting
(CONTINUED)

- The changes which the U.S. developed for the Preamble to the overall Principles and to Principle 2 ("Use of terms") had the effects of

  - Making the use of nuclear power sources a technical decision as the 1981 U.N. technical report stated.

  - Eliminating nuclear propulsion and future nuclear power sources (those not currently in existence) from the Principles.

  - Requiring future revisions to recognize that trying to legislate rigid standards of radiological protection was inconsistent with the evolving national and international standards of radiological protection.

  - Defining the terms "foreseeable" and "all possible" to mean, in effect, "credible".

  - Defining the term "defense-in-depth" to give the necessary flexibility for space applications.

  - Defining the term "made critical" to allow zero-power testing of reactors before launch.

- The modified Preamble also brings in the basic concept that the Principles are to provide safety goals and guidelines rather than (by inference) arbitrary numerical dose limits that have no relationship to accidents. The Preamble also mentions the term "risk" rather than the undefined word "hazards" and the Preamble describes the need for probabilistic risk assessments (which is the U.S. approach).

Concluding Remarks

- Overall, the meeting of the (U.S.) Ad-Hoc Working Group achieved its objective of providing a common set of changes to U.N. draft Principle 3 ("Guidelines and criteria for safe use"). Most of this minimal set of changes requested by the Ad-Hoc Working Group was incorporated into the overall principles (generally in the overall Preamble or in Principle 2 ["Use of terms"]).

- In other areas where the U.S. was not able to make the requested specific changes (e.g., "shall" versus "should", Section 1.3's dose limits, Section 3.2's absolute containment, etc.), U.S. delegates presented formal statements describing how the U.S. intended to interpret the Principles.

- This process also showed that it is possible for knowledgeable, rational technical experts to work together to correct a political document that contained many technical flaws.