PROPOSED PRINCIPLES ON THE USE OF NUCLEAR POWER SOURCES IN SPACE

889027

Gary L. Bennett*
Office of Special Applications
U.S. Department of Energy
Washington, D.C. 20545

ABSTRACT

Since the 1978 reentry of the Soviet satellite Cosmos 954, the United Nations has been discussing the use of nuclear power sources in outer space. Most of these deliberations have taken place in the U.N. Committee on the Peaceful Uses of Outer Space, its two subcommittees (Scientific and Technical Subcommittee and Legal Subcommittee) and their associated working groups. This paper focuses on the technical agreements reached by the Working Group on the Use of Nuclear Power Sources in Outer Space (WGNPS), the legal principles agreed to by the Legal Subcommittee, and relevant treaties on the use of outer space and the use of nuclear power. The 1981 WGNPS report states "Provided the additional risks associated with NPS are maintained at an acceptably low level, the Working Group considered that the basis of the decision to use NPS should be technical." To date the conclusion reached by the WGNPS in its 1981 report represents a succinct statement of U.N. consensus and of the U.S. position: "the Working Group reaffirmed its previous conclusion that nuclear power sources can be used safely in outer space, provided that all necessary safety precautions are met."

BACKGROUND

Over the years there have been continuing discussions within the U.N. on proposed principles for the use of nuclear power sources (NPS) in outer space. Occasionally there have been misunderstandings on U.S. policy and on U.N. activities relating to the use of NPS in outer space. The purpose of this paper is to summarize the main points regarding the use of NPS as developed in various treaties, conventions, and U.N. documents. Since these treaties, conventions, and U.N. documents were supported by the U.S. they also provide a summary of U.S. policy over a span of about 20 years.

The focus of this paper will be on the general principles as developed by the international community. Specific nuclear and radiological safety guidance for the various phases (including ground operations) of a given mission may be found in the NPS program's safety documents, Department of Energy (DOE) Orders, the U.S. Code of Federal Regulations, the National Council on Radiation Protection and Measurements (NCRP), etc.

With respect to treaties and conventions there are six which govern U.S. activities in space. Four of these treaties cover U.S. activities whether nuclear or nonnuclear and two touch on nuclear activities in space. The six treaties are (with dates they entered into force indicated in parenthesis along with the short title used in this paper):

- Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies (10 October 1967; this treaty is generally referred to as the "Outer Space Treaty");
- Agreement on the Rescue of Astronauts, the Return of Astronauts and the Return of Objects Launched into Outer Space (3 December 1968; this treaty is sometimes referred to as the "Rescue Agreement");
- Convention on International Liability for Damage Caused by Space Objects (9 October 1973; this treaty is generally referred to as the "Liability Convention");
- Convention on Registration of Objects Launched into Outer Space (15 September 1976; this treaty is generally referred to as the "Registration Convention");
- Convention on Early Notification of a Nuclear Accident (27 October 1986; this treaty will be referred to as the "Notification Convention"); and
- Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency (26 February 1987; this convention will be referred to as the "Assistance Convention").

A fifth treaty, the Agreement Governing Activities of States on the Moon and Other Celestial Bodies (the "Moon Treaty"), was adopted by the U.N. General Assembly (UNGA) on 5 December 1979 and entered into force on 11 July 1984, although neither the U.S. nor the USSR has signed the treaty. Nevertheless, the Moon Treaty has a certain "moral force" behind it and will be noted as appropriate in this paper. The provisions of the Moon Treaty also apply to other celestial bodies within the solar system (other than the Earth) and to orbits around or other trajectories to or around the Moon. (In 1986, the U.N. Committee on the Peaceful Uses of Outer Space (COPUOS) agreed on a draft set of Principles Relating to Remote Sensing of the Earth from

* Member, U.N. Working Group on the Use of Nuclear Power Sources in Outer Space.

Space; however, these principles add nothing that is not covered in the previously listed treaties regarding NPS.)

While not legally binding, there are a number of reports that have come out of the Scientific and Technical Subcommittee (STSC) and the Legal Subcommittee (LSC) of COPUOS dealing with the use of NPS in outer space. These reports were motivated by the two Soviet space reactor reentry accidents: Cosmos 954 in 1978 and Cosmos 1402 in 1983. The STSC formed a Working Group on the Use of Nuclear Power Sources in Outer Space (WGNPS) which met from 1979 to 1981 and in 1981 produced a consensus technical report that still represents the best summary of international technical opinion on this subject. In 1986 the LSC (and subsequently COPUOS) adopted two principles derived from the 1981 WGNPS report. Reference 1 provides a good historical summary of the U.N. activities regarding NPS.

SAFETY PHILOSOPHY

The Outer Space Treaty begins with a preamble that notes "the great prospects opening up before mankind as a result of man's entry into outer space" and recognizes "the common interest of all mankind in the progress of the exploration and use of outer space for peaceful purposes". While the Outer Space Treaty forbids the establishment of military bases or testing of weapons on the Moon and other celestial bodies, it does unequivocally state that "The use of any equipment or facility necessary for peaceful exploration of the moon and other celestial bodies shall also not be prohibited".

Article IX of the Outer Space Treaty enjoins States to avoid harmful contamination of the Moon and other celestial bodies. It also requests States planning to conduct an activity or experiment that "would cause potentially harmful interference with activities of other States Parties in the peaceful exploration and use of outer space" to "undertake appropriate international consultations before proceeding with any such activity or experiment."

The Moon Treaty requests States Parties to take measures "to prevent the disruption of the existing balance of its environment" including avoiding "harmful contamination". States Parties are also requested to notify the Secretary-General of the United Nations, to the maximum extent feasible, in advance "of all placements by them of radio-active materials on the moon and of the purposes of such placements".

The 1981 WGNPS report noted that NPS "require that appropriate design and operational measures be taken, in order to protect the population and the environment for both normal and accidental conditions." The report goes on to state that "the risks inherent in each particular application or project are to be assessed in terms both of the probability of failure or malfunction and the severity of its consequences". The WGNPS recognized that for "certain important space missions NPS have been the preferred technical choice. Provided the additional risks associated with NPS are maintained at an acceptably low level, the Working Group considered that the basis of the decision to use NPS should be technical".(2) (Emphasis added.)

The Outer Space Treaty, the Rescue Agreement, and the Moon Treaty variously identify other important principles such as

- States Parties should render all possible assistance to astronauts in the event of an accident and astronauts of one State Party should render all possible assistance to the astronauts of other States Parties;
- States Parties bear international responsibility for national activities in outer space;
- All stations, installations, equipment and space vehicles on the Moon and other celestial bodies are open to visits (with reasonable advance notice) from representatives of other States Parties on a basis of reciprocity.

The following sections consider in more detail certain important principles.

SAFETY CRITERIA

In its 1981 report the WGNPS "agreed that appropriate measures for adequate radiation protection during all phases of an orbital mission of a spacecraft with NPS - launch, parking orbit, operational orbit, or re-entry - should be derived where relevant from the existing, and internationally recognized basic standards recommended by ICRP (International Commission on Radiological Protection), in particular ICRP publication 26". The key phrase is "where relevant" since the "Working Group noted that ICRP publication 26 does not provide specific guidance for accidents and emergencies although it does address in general terms the circumstances in which remedial action might be taken". In fact, the WGNPS was well aware that "in some possible accident situations, the dose limits of ICRP publication 26 could be exceeded".(2)

Bearing these factors in mind, the WGNPS considered the general safety criteria for radioisotope systems and U-235-fueled reactor systems. (The WGNPS chose to limit their report to U-235-fueled reactors because that was all that was reportedly being flown. The WGNPS was aware of a U.K. working paper which noted that in comparison with U-235 "a plutonium fueled reactor would be a somewhat greater risk, but it would take many times the five tonnes of plutonium dispersed in weapon tests before the hazard from fissile material could dominate" (3).)

The WGNPS "noted that the safety of radio-isotope systems was being assured by designing them to contain with a high probability of success the radio-isotope for normal and credible abnormal conditions. The design should ensure minimal leakage of the radio-active contents with a reasonably high level of probability of success in all credible circumstances including launch accidents, re-entry into the atmosphere, impact and water immersion. The appropriate limits

recommended by the International Commission on Radiological Protection (ICRP) should be met for normal operational conditions."(2)

The 1981 WGNPS report goes on to state that the "Working Group agreed that the safety of U-235 reactor systems did not present any difficulty when they were started and operated in orbits sufficiently high to give time for radio-active materials to decay to a safe level in space after the end of the mission. In this way the dose equivalents at the time of re-entry could be guaranteed in all circumstances to be within the limits recommended by ICRP for non-accident conditions. If reactors are intended for use in low orbits where the radio-active materials do not have sufficient time to decay to an acceptable level, safety depends on the start of the operation in orbit and the success of boosting NPS to a higher orbit after operation is completed. In the event of an unsuccessful boost into higher orbit the system should in all credible circumstances be capable of dispersing the radio-active material so that when the material reaches the earth the radiological situation conforms to the recommendations of ICRP when relevant."(2)

In 1987 the Canadian delegation proposed a modification to this philosophy in a working paper which stated that "Nuclear reactors shall be designed either to reenter the Earth's atmosphere and land while maintaining the functional integrity of the containment of radioactive materials, or to divide and disperse into fine particles the radioactive materials upon reentry into the Earth's atmosphere . . ."(4) The subject of maintaining the functional integrity of the containment was favorably discussed in the 1988 meeting of the WGNPS and will be considered further by that group.(5)

In 1988 the WGNPS considered two more safety criteria relating to space reactors (5):

- "The Working Group considered it necessary to study the problem that the design of a nuclear power source should cope with the risk of internal events occurring in space, such as a failure of normal systems for removing heat, with the objective of maintaining the containment of solid radioactive materials in all credible accidents."

- "The Working Group was of the opinion that, if the core of a nuclear reactor returning to the Earth becomes flooded for any reason, it should, by virtue of design, satisfy the safety criterion of remaining sub-critical in all credible scenarios."

For several years both the WGNPS and the LSC have been discussing the criterion that reactors on board space objects intended for use in orbits around the Earth shall not be activated until they have reached their planned operating orbit. The WGNPS has also heard discussions on in-space recovery techniques and the possibility of damage to NPS from space debris. With regard to the latter, in 1988 the "Working Group encouraged national studies of this issue and invited delegations to present related results to the Scientific and Technical Sub-Committee." (5)

NOTIFICATION

The Notification Convention, which was developed following the 1986 Chernobyl accident, calls upon the State Party having a nuclear accident to notify affected States directly or through the International Atomic Energy Agency (IAEA). The information to be provided includes

- The time, exact location where appropriate, and the nature of the nuclear accident;

- The facility or activity involved;

- The assumed or established cause and the foreseeable development of the nuclear accident relevant to the transboundary release of the radioactive materials;

- The general characteristics of the radioactive release, including, as far as is practicable and appropriate, the nature, probable physical and chemical form and the quantity, composition and effective height of the radioactive release;

- Information on current and forecast meteorological and hydrological conditions, necessary for forecasting the transboundary release of the radioactive materials;

- The results of environmental monitoring relevant to the transboundary release of the radioactive materials;

- The off-site protective measures taken or planned; and

- The predicted behavior over time of the radioactive release.

The Notification Convention calls for updates at appropriate intervals. The Registration Convention calls upon each State of registry to notify the Secretary-General of the United Nations "to the greatest extent feasible and as soon as practicable, of space objects concerning which it has previously transmitted information, and which have been but no longer are in earth orbit". The Moon Treaty calls upon a "State Party which learns of the crash landing, forced landing or other unintended landing on the moon of a space object, or its component parts, that were not launched by it" to "promptly inform the launching State Party and the Secretary-General of the United Nations".

U.N. General Assembly (UNGA) resolution 33/16 of 10 November 1978 requests launching States to inform States concerned in the event that a space object with NPS on board is malfunctioning with a risk of reentry of radioactive materials to the Earth. Building upon the UNGA resolution, the 1981 WGNPS report, and the Registration Convention, the LSC and COPUOS agreed to the following -- and, as yet, nonbinding -- principle on notification:

1. Any State launching a space object with nuclear power sources on board should* timely inform States concerned in the event this space object is malfunctioning with a risk of

re-entry of radioactive materials to the Earth. The information should be in accordance with the following format:

1. System parameters

   1.1 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

   1.2 International designation

   1.3 Date and territory or location of launch

   1.4 Information required for best prediction of orbit lifetime, trajectory and impact region

   1.5 General function of spacecraft

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

   2.1 Type of NPS: radio-isotopic/reactor

   2.2 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 should also be transmitted to the Secretary-General of the United Nations.

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

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

4. 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.

ORBIT PREDICTION

Article VI of the Registration Convention addresses the issue of States Parties with space monitoring and tracking facilities aiding an affected State in identifying a space object which has caused damage to it or which may be of a hazardous or deleterious nature.

The WGNPS was aware that notification could be greatly facilitated if the accuracy of orbital predictions (then stated to be about ± 10 percent) could be improved. The report noted that "Accuracy could be improved by the implementation of additional degrees of control, further research and study and by extensive and cooperative use of tracking stations and communications lines".(2)

SEARCH AND RECOVERY

The Assistance Convention states that States Parties shall cooperate between themselves and with the IAEA "to facilitate prompt assistance in the event of a nuclear accident or radiological emergency to minimize its consequences and to protect life, property and the environment from the effects of radioactive releases." The Assistance Convention sets out the principles governing the provision of assistance, the direction and control of assistance, the need to identify competent authorities and points of contact, the functions of the IAEA, and various operational issues such as movement of personnel and equipment and reimbursement of costs.

Under the Rescue Agreement, a launching State is obliged, at the request of a State affected, to eliminate possible damage or harm that might result from the return of a space object. Under the terms of the Outer Space Treaty a launching State is obliged to examine the possibility of rendering appropriate and rapid assistance to a State suffering damage caused by a space object which presents a large-scale danger to human life or seriously interferes with the living conditions of the population or the functioning of vital centers, when the affected State so requests.

Both the Assistance Convention and the 1981 WGNPS report discuss the need for emergency planning. Under the Assistance Convention the IAEA is empowered to assist in emergency planning if so requested.

In 1986, the LSC and COPUOS agreed to the following principle on assistance:

After reentry 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;

---

* The question whether the term "should" or "shall" is to be used in the texts is to be considered later.

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 should be taken into account.

LIABILITY

The U.N. was well aware that the human race could not travel in space without risk; this awareness was aptly noted in the preamble to the Liability Convention with the "consideration that, notwithstanding the precautionary measures to be taken by States and international intergovernmental organizations involved in the launching of space objects, damage may on occasion be caused by such objects . . ."

The Liability Convention states that "A launching State shall be absolutely liable to pay compensation for damage caused by its space object on the surface of the earth or to aircraft in flight." If the damage occurs elsewhere the launching State "shall be liable only if the damage is due to its fault or the fault of persons for whom it is responsible." The Liability Convention establishes the degree of liability for various conditions (such as two- or three-party involvement), compensation, the method for presenting claims, and the establishment of a Claims Commission.

CONCLUSIONS

Existing treaties and conventions provide a general basis and appropriate principles for the use of nuclear power sources in outer space. U.S. practices in this area are consistent with these general principles.(6) Considering these factors the 1981 WGNPS report's conclusion still remains valid, namely "that NPS can be used safely in outer space, provided that all necessary safety requirements are met."(2)

REFERENCES

1. G. L. Bennett, J. A. Sholtis, and B. C. Rashkow, "United Nations Deliberations on the Use of Nuclear Power Sources in Space: 1978-1987," to be published in Space Nuclear Power Systems 1988.

2. "Report of the Working Group on the Use of Nuclear Power Sources in Outer Space on the Work of Its Third Session," Annex II of Report of the Scientific and Technical Subcommittee on the Work of Its Eighteenth Session, U.N. Document A/AC.105/287, 13 February 1981.

3. United Nations, "Question Relating to the Use of Nuclear Power Sources in Outer Space, Report of the Secretariat," U.N. Document A/AC.105/220, United Nations, 20 May 1978.

4. Canada, "The Elaboration of Draft Principles Relevant to the Use of Nuclear Power Sources in Outer Space," working paper submitted by Canada to the Legal Subcommittee of the U.N. Committee on the Peaceful Uses of Outer Space, U.N. Document A/AC.105/C.2/L.154/Rev. 1, United Nations, 12 March 1987.

5. "Report of the Working Group on the Use of Nuclear Power Sources in Outer Space on the Work of Its Sixth Session," Annex III of Report of the Scientific and Technical Subcommittee on the Work of Its Twenty-Fifth Session, U.N. Document A/AC.105/409, 1 March 1988.

6. G. L. Bennett, "Flight Safety Review Process for Space Nuclear Power Sources", Paper 879046, Proceedings of the 22nd IECEC, 10-14 August 1987, Philadelphia, Pennsylvania.

* The question of the definition of the term "affected State" is to be considered later.

1988 IECEC
JULY 31–AUGUST 5
DENVER, COLORADO

Participating Societies

PROCEEDINGS OF THE 23rd INTERSOCIETY ENERGY CONVERSION ENGINEERING CONFERENCE

VOLUME 3

Aerospace and Space Power
Photovoltaics
Space Nuclear Power
Space Power Automation
Space Power Computer Simulation
Space Station Power
Pulse/Megawatt Space Power
MHD for Space
Space High Voltage
Spacecraft Power Systems

Editor
D. YOGI GOSWAMI

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS
United Engineering Center 345 East 47th Street New York, N.Y. 10017