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Use of nuclear power sources in outer space

Identification of terrestrial processes and technical standards with a possible relevance to nuclear power sources, including factors distinguishing the use of nuclear power sources in outer space from terrestrial nuclear power applications

Working document submitted by the Russian Federation

1. Under the work plan for developing a framework on safety assurance processes and standards for nuclear power sources in outer space, adopted by the Scientific and Technical Subcommittee, the Russian Federation is hereby submitting a working document setting out its research findings on provisions, norms, rules and standards of relevance to the safety of nuclear power sources (NPS), taking account of the factors distinguishing the use of NPS in space from terrestrial applications of nuclear power.

2. The following national and international documents establishing requirements for the safe use of NPS were examined and analysed:

(a) Recommendations of the International Commission on Radiological Protection, publications Nos. 1-68, 1958-1994;

(b) Standards and guides of the International Atomic Energy Agency (IAEA), Safety Series, 1975-1997;

(c) Russian national radiation protection standards (NRB-76/87, NRB-96) and basic health regulations (OSP-72/87).

3. Analysis of those documents shows that, during terrestrial phases of the operation of space NPS (storage, transport and preparation for launching at the launch site), the safety requirements adopted for terrestrial nuclear power are also applicable to space NPS and

are fully observed, as confirmed by the experience of many years in the design and operation of space reactor and radioisotopic NPS.

4. During the operating phases of space NPS on board carrier rockets or space objects and when they remain in space for prolonged periods after their withdrawal from operation, the following criteria may be proposed as being necessary and sufficient for ensuring the safe operation of space NPS:

(a) Dose limit restriction within a range of 0.1-1.0 mSv in a year; for example, to the level of the most probable deviations from the average dose range of radiation exposure of the public from natural sources, which amounts to approximately 0.3 mSv in a year;

(b) Containment of the effects of accidents in the sense of minimizing the potential release of radioisotopes from NPS into the natural environment, including outer space;

(c) Regulation of NPS, carrier rocket and space object reliability and of launching rates as a function of the power and service life of NPS and the possible release of radioactive isotopes from NPS in the event of an accident.

5. The first criterion (dose limit restriction within a range of 0.1-1.0 mSv in a year) has the following scope:

(a) Normal operation of NPS on board carrier rockets and space objects;

(b) Prolonged stays of NPS in a sufficiently high orbit after their withdrawal from operation, account being taken of a possible collision of NPS with space debris;

(c) Launching pad accidents involving carrier rockets transporting space objects with NPS on board and orbital entry of space objects with NPS on board into the atmosphere in situations where the radio nuclide ampoule in radioisotopic NPS remains intact or where, in the case of reactor NPS, the “cold” non-activated reactor remains subcritical.

6. Destruction of the radionuclide ampoules with ejection of propellant materials and criticality of the “cold” non-activated reactor are considered to constitute a nuclear accident and/or radiation accident if the main dose levels are raised, it being understood that the probability of such incidents is fairly small.

7. The second criterion (containment of the effects of an accident in the sense of minimizing the potential release of radioisotopes from NPS into the natural environment, including outer space) accords with the general principle of defence in-depth and requires technical solutions to be directed towards fulfilling the special requirements of space NPS systems and components.

8. The third criterion (regulation of NPS, carrier rocket and space object reliability and of launching rate as a function of the power and service life of NPS and the potential release of radioisotopes from NPS in the event of an accident) dictates the need for a sensible compromise in establishing the reliability criteria for the safety systems and structural elements of NPS, taking account of the reliability of carrier rockets and space objects and the probability of accidents involving the fall of NPS into inhabited areas.

9. The probability of extreme events resulting in damage can be estimated for the fall of an NPS on the basis of the following probabilities: the probability of the accident, the probability of the accident meeting the parameters for producing effects, the probability of the destruction or non-destruction in an accident of the impact-bearing safety systems and structural elements, the probability of descent onto a given part of the Earth’s surface, the probability of discovery and removal from the descent site, the probability of prolonged

contact between the nuclear fuel and the environment and the probability of nuclear fuel being dispersed throughout the environment in such a way as to affect the population.

10. The proposed supplementary principles related to risk justification, limitation and reduction and to the corresponding numerical values (generally accepted and minimum) should be replaced by provisions on tolerable damage and on the probabilities of accidents in which the annual dose limits for exposure of the public might be reached or in which levels of exposure of the public similar to those caused by accidents classified as nuclear and/or radiation accidents might be reached.

11. In addition to principles concerning the use of NPS in space, it might also be considered acceptable to adopt provisions on safety culture, safeguards and contamination of outer space.

12. Safety culture can be defined as follows:

"The responsibility of employees of the NPS designer and manufacturer and employees of the operating organization, the training and qualifications of staff, the psychological preparation of employees to view NPS safety as a priority aim, discussion of the findings of the exploration of safety issues in the design and construction of NPS, follow-up on decisions taken, the drafting and approval of final documentation, decision-making by national authorities regarding the launching of space objects with NPS on board and the furnishing of information in an established format."

13. Safeguards (physical protection of nuclear material) can be defined in accordance with an IAEA convention on the basis of the confidentiality of the information transmitted regarding the site (region) of NPS descent in an accident involving the launch of a carrier rocket or in the flight phase of the carrier rocket in which the space object with the NPS on board is injected into working orbit or during the orbital re-entry of the space object with the NPS on board into the Earth's atmosphere.

14. The principle of outer space contamination is defined in accordance with the proposed criterion on minimization of the possible ejection of radioisotopes from NPS where no limitations are imposed on the level of ionizing radiation from NPS (neutron, proton, gamma, electron and positron) in operation on board space objects and during temporary but prolonged stays in a relatively high orbit after withdrawal of the NPS from operation.

15. It is proposed to delete from the preamble to the Principles Relevant to the Use of Nuclear Power Sources in Outer Space (General Assembly resolution 47/68) the following paragraph:

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

16. This is important, firstly, to eliminate the ambiguity of this paragraph, for example, that the principles are applicable only to NPS used for supplying electric power to the on-board systems of space objects, whereas other applications of NPS on board space objects are prohibited, or that the principles apply only to NPS used for supplying electrical power to the on-board systems of space objects, but do not apply to other uses of NPS so that the designer is justified in acting according to his own discretion.

17. Secondly, deletion of the above paragraph is important in order to extend the operation of the principles to all applications of NPS in space, including nuclear engines

based on the technology of nuclear rocket engines, nuclear power units with electroreactive engine units, bimodal nuclear power units, NPS used in the thermostatic regulation of the on-board systems of space objects and NPS used as sources of ionizing radiation.