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COMMITTEE ON THE PEACEFUL
USES OF OUTER SPACE

USE OF NUCLEAR POWER SOURCES IN OUTER SPACE

Working paper submitted by the Russian Federation

During the period 1970-1988, the former Union of Soviet Socialist Republics (USSR) launched the series of Cosmos spacecraft carrying nuclear power sources (NPS) on board. NPS included fast neutron reactors, radiation shielding, a thermoelectric system of converters and two circuits of semiconductor heat conductors (liquid sodium-potassium). Nuclear-powered spacecraft were launched into a low operating orbit of 265 kilometres, with later insertion of NPS into a high orbit of 900-1,000 kilometres on completion of the operational life of the spacecraft. In this connection, beginning in 1980 with the insertion of the Cosmos 1176 satellite into a high orbit, the heating element assembly was ejected from the body of the reactor together with the primary heat conductor circuit.

In 1990, the USSR provided the Committee on the Peaceful Uses of Outer Space with a full list of nuclear-powered spacecraft launched. A total of 33 satellites were launched, starting with the Cosmos 367 satellite and ending with the Cosmos 1932 satellite, including two satellites with thermonuclear reactors in an operating orbit of 800 kilometres. As a result of failures in the systems for insertion into high orbit, Cosmos 954 and Cosmos 1402 entered the dense layer of the Earth's atmosphere and were destroyed. The NPS of Cosmos 1900 were inserted in an orbit of 720 kilometres.

Consequently, in high orbits of 700-1,000 kilometres, there are currently 15 nuclear power plants with nuclear fuel and semiconductor heat conductors, 16 fuel element assemblies with nuclear fuel and 16 NPS without nuclear fuel and with secondary-circuit semiconductor heat conductors.

Research shows that ejection of high-temperature primary-circuit heat conductors results in evaporation of liquid sodium-potassium into fine particles. Because of the speed of evaporation of particles from the body of the reactor and the direction of ejection, counter to the direction of flight, the particle cloud falls from orbit and enters the dense layer of the atmosphere. The level of activity in the sodium-potassium at the time the reactor is shut down is of the order of 10 curies; the half-life, depending on the quantity of sodium 24 and potassium 42 isotopes, is less than 15 hours, and it decays almost completely within a matter of weeks.

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Such a practice applied to reactor NPS in space fully complies with the Principles Relevant to the Use of Nuclear Power Sources in Outer Space, adopted by the General Assembly in its resolution 47/68.

Concerning the importance of research into the problem of collision of NPS with space debris, research is being carried out in the Russian Federation into the process of destruction of NPS assemblies and fuel element assemblies in the event of collision with debris of different sizes, the change in the flight trajectory parameters of the fragments and particles, entry into the dense layer of the atmosphere and aerodynamic destruction, with an estimate of possible radioactive fallout of dispersed particles of nuclear fuel. The basic results of the research has been published annually since 1991 in working documents submitted by the Russian Federation to the Committee on the Peaceful Uses of Outer Space.

The process of destruction of sealed circuits of semiconductor heat conductors in the event of collision of NPS with space debris is especially important. The possible consequences may be estimated from the thermal condition of parts of the circuit elements during periodic freezing and melting of sodium-potassium under the effects of solar radiation, from the nature and scale of the damage, and from the formation of droplets of sodium-potassium and their subsequent dispersal in space. Research into these processes will require a significant amount of work and several experiments with active assemblies. Such research is envisaged in the Russian Federation EKOS-RF programme.

In developing future space NPS, measures to ensure safety (radiation, nuclear, ecological) will be aimed at minimizing the effects of ionizing emissions and of radioactive and toxic materials on the population and the environment, including outer space. The safety of space NPS at all stages of their operation and in the event of foreseeable accidents will be ensured by safety systems and NPS structural elements designed to meet safety requirements, and by special comprehensive administrative and technical measures to prevent accidents and eliminate the effects of accidents. The structure and effectiveness of the NPS safety systems and structural elements of space NPS will result in the consequences of accidents having a minimal effect on the population and the environment, reducing them naturally, through migration and dispersal of radioisotopes and toxic materials and by design, using appropriate technical methods for the removal of radioisotopes and toxic materials. The reliability of the safety systems and of structural elements of space NPS with regard to safety, taking into account the reliability of the carrier rockets and spacecraft, ensures a minimal risk of accidental damage to NPS having an impact on the population of a country.

The safety of space NPS and the elimination of the risk associated with the use of NPS in spacecraft are based on:

(a) Analysis of foreseeable likely occasions of damage at all stages of operation of NPS and the parameters of the effects on NPS in the event of an accident;

(b) The condition of NPS structural elements carried and of safety systems in the event of an accident;

(c) Determining, theoretically and experimentally, the effectiveness of NPS safety systems and NPS structural elements, with regard to safety, in the event of accidents, including possible collisions of the spacecraft and NPS with space debris during long-term service in space;

(d) Improving the reliability of NPS safety systems and NPS structural elements by testing their models;

(e) Determining the risk of radiological and chemical damage to the environment in the event of accidents, taking into account the probability of accidents; the probability of collision with space debris; the probability of reaching parameters relating to the impact of accidents; the reliability of the carrier rocket, the spacecraft, the safety systems and the NPS structural elements; and the probability of dispersal of radioactive isotopes and toxic materials in the environment, entailing effects on the population;

(f) Comprehensive administrative and technical measures to prevent and suppress the effects of accidents, including forecasting the area where NPS will fall, search for and detection of NPS, removal of NPS and individual parts from the place of descent and, where necessary, deactivation;

(g) Probability analysis of potentially serious radiological and ecological effects in respect of specific NPS, taking account of the purpose and flight programme of spacecraft, using various methods and devices, and combinations thereof, to ensure the safety of NPS, thus making it possible to estimate the risk of launching NPS in a spacecraft.