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Use of nuclear power sources in outer space

Joint statement made by representatives of the Russian Federal Space Agency and the State Atomic Energy Corporation "Rosatom" at the seminar of the Scientific and Technical Subcommittee of the Committee on the Peaceful Uses of Outer Space on the Safety Framework for Nuclear Power Source Applications in Outer Space: current and planned applications, and challenges

Submitted by the Russian Federation

The United Nations Safety Framework for Nuclear Power Source Applications in Outer Space (hereinafter referred to as "the Safety Framework") notes that "according to current knowledge and capabilities, space NPS are the only viable energy option to power some space missions and significantly enhance others. Several ongoing and foreseeable missions would not be possible without the use of space NPS."

Russian experts fully subscribe to that view and consider it necessary to highlight the special role of reactor nuclear power sources in the further development of space exploration. Reactor NPS were created in the Union of Soviet Socialist Republics (USSR) and the United States of America during the last century, and were used successfully in space until the end of the 1980s.

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* This paper is also available without images, edited and in all official languages of the United Nations, in document A/AC.105/C.1/L.320.

** A/AC.105/C.1/L.310.

Russian experts consider that the use of reactor nuclear power in space on the basis of the latest technologies, together with the creation of nuclear power propulsion units (NPPU), are essential in order to meet current and future challenges in near and deep space and to develop space exploration in the twenty-first century.

The main advantages of using reactor nuclear power rather than solar power in space include the following:

- The production of electrical energy from reactor NPS is not dependent on the light available in orbit, the orientation of the space vehicle or distance from the sun, thus making deep space missions possible
- The possibility of ensuring the high power output of energy supply systems aboard space vehicles
- The possibility of using high-efficiency plasma engines
- Transition to state-of-the-art energy- and cost-efficient space transport systems

In light of the above, and in accordance with a decision of the Presidential Commission for the Modernization and Technological Development of the Russian Economy, an innovative project to create a transport energy module (TEM) with a megawatt-class NPPU is currently being carried out within the framework of cooperation among a group of Russian enterprises headed by the Russian Federal Space Agency (Roscosmos) and the State Atomic Energy Corporation "Rosatom".

The main phases of the project are:

2012 — the drawing up of preliminary designs for the NPPU and TEM

2018 — preparation of the TEM for design test flights

The TEM will provide an effective solution to a wide range of major practical challenges, thus contributing to space exploration and science and to the promotion of socio-economic progress.

The project to develop a TEM with a megawatt-class NPPU is being implemented on the basis of the extensive experience of the Russian Federation in the creation and safe use of first-generation space reactor NPS, which use thermoelectric (in the case of Buk reactors) and thermionic (in the case of Topaz reactors) converters to convert thermal energy into electricity.

Two Plasma-A satellites with a Topaz reactor NPS, an electrical output capacity of 5 kilowatts and electric rocket propulsion units were launched into orbit in 1987.

As early as the 1960s, during the initial phase of the creation of space vehicles with first-generation reactor NPS, the USSR developed solutions for ensuring nuclear and radiation safety during their operation.

Those solutions were subsequently endorsed by the United Nations Committee on the Peaceful Uses of Outer Space and are enshrined in the Principles Relevant to the Use of Nuclear Power Sources in Outer Space, which were approved by the United Nations General Assembly in 1992.

During work to ensure the safety of space reactor NPS while in operation, methods of isolating NPS from the Earth's biosphere and dispersing them in the event of their emergency return to Earth were developed and partially implemented.

It should be noted that the Russian Federation also has experience in the construction and safe operation of radioisotope NPS aboard space vehicles. A radioisotope NPS was used aboard the mobile lunar laboratory "Lunokhod". Russian experts have successfully resolved the problem of how to preserve intact all ampoules containing radioisotopic materials in the event of the emergency return of NPS to Earth at second cosmic velocity (escape velocity).

Russian experts are developing the prototype TEM and megawatt-class NPPU in full compliance with international recommendations relating to space NPS. They are also conducting their activities in relation to construction of the TEM in accordance with national federal laws, including the Space Activities Act, the Act on the Use of Atomic Energy, the Act on Protection of the Public from Radiation, the Environmental Protection Act, the Environmental Assessment Act and regulations such as the Radiation Safety Standards and the Basic Public Health Regulations for Radiation Safety.

All laws and regulations of the Russian Federation relating to the use of atomic energy are in full conformity with international instruments.

Two instruments ensuring the safety of nuclear power applications in space, drawn up by the Committee on the Peaceful Uses of Outer Space and approved by the General Assembly, are of particular importance: the Principles Relevant to the Use of Nuclear Power Sources in Outer Space and the Safety Framework for Nuclear Power Source Applications in Outer Space.

Despite their non-binding status, those instruments have been strictly observed by Russian experts in developing the prototype TEM and megawatt-class NPPU. This is reflected in the terms of reference for the project.

The Safety Framework states that "foreseeable space NPS applications include [...] nuclear reactor systems for power and propulsion". Accordingly, the TEM, which contains a nuclear power facility and an electrically powered cruise propulsion system fed by that facility and designed to propel the space vehicle and supply power to all its systems, is being developed in full conformity with the relevant recommendations of the United Nations.

Work on the construction of the TEM is being carried out in full compliance with the fundamental safety objective set out in the Safety Framework as follows: "The fundamental safety objective is to protect people and the environment in Earth's biosphere from potential hazards associated with relevant launch, operation and end-of-service phases of space nuclear power source applications."

The guidance set out in the Safety Framework for fulfilling that fundamental safety objective is divided into three categories:

- Guidance for governments
- Guidance for the management personnel of organizations conducting space NPS missions and
- Technical guidance

Governmental responsibilities include establishing safety policies, requirements and processes; ensuring compliance with those policies, requirements and processes; ensuring that there is acceptable justification for using a space NPS when weighed against other alternatives; establishing a mission launch authorization process; and ensuring emergency preparedness and response.

In connection with the development of the TEM and NPPU, and taking into account the provisions of relevant international instruments, national regulations in the Russian Federation are currently being updated. They include:

- General safety provisions for space nuclear power installations
- Nuclear safety regulations for space nuclear power installations
- Public health regulations for ensuring the radiation safety of space nuclear power sources and
- Requirements relating to the content of safety assessment reports for space nuclear power installations

The Safety Framework states that the management of organizations involved in space NPS applications should comply with governmental safety policies, requirements and processes in order to achieve the fundamental safety objective.

Management responsibilities include ensuring the availability of adequate resources for safety, promoting and sustaining a robust safety culture at all organizational levels and providing relevant, accurate and timely information to the public.

The measures necessary in order to fulfil those requirements have been implemented, including the establishment of a council comprising the heads of the enterprises participating in the TEM project and a working group for coordinating activities relating to the adoption of technical solutions for ensuring nuclear and radiation safety during the construction and operation of the TEM.

The groups comprise leading experts from all the entities participating in the project. Information is provided to the public in a timely manner through the mass media.

The guidance provided in the Safety Framework with regard to the need to consider nuclear safety from the earliest stages of design and development and throughout all mission phases forms the basis for the work currently being carried out in the Russian Federation to develop the TEM and its NPPU.

In designing the TEM and its constituent parts, conducting tests and assessing nuclear and radiation safety, experience in developing nuclear rocket engines and previous-generation space nuclear power installations will be drawn upon.

The NPPU reactor will not be made critical before the TEM has reached a sufficiently high operating orbit or been directed into an interplanetary trajectory. The nuclear reactor is constructed in such a way as to ensure that it is maintained in subcritical condition before entering operating orbit or an interplanetary trajectory in the event of any potential incident, including explosion of the carrier rocket, re-entry into the atmosphere, impact on land or water, submersion in water or the entry of water into the reactor core.

Options are being considered with regard to a system for deorbiting the TEM using a special unit in case of failure of delivery into a nuclear-safe orbit.

The altitude chosen for the initial orbit of the TEM, at which the nuclear reactor will enter into operation, reflects the guidance for ensuring the maximum possible level of safety. At the current stage of design of the TEM and its NPPU, a sufficiently high orbit has been selected as the initial orbit and as the orbit to which the TEM can return when operating in inter-orbital transfer mode. Thus, operational safety has been given priority over operational efficiency.

A preliminary analysis has shown that the minimum altitude of the TEM orbit should be above the range of 800 to 1,000 kilometres — i.e., the zone in which the density of near-Earth space debris is greatest. Consequently, in order to meet guidelines for minimizing the probability of collisions with other space objects, altitudes between 1,200 and 2,000 km are being considered as minimum possible altitudes for TEM flights.

With regard to the use of the TEM as part of an inter-orbital transfer vehicle to deliver a payload module into geostationary orbit, a system for such use that eliminates any possibility of danger to the Earth's population has been developed. If the TEM is used in such a way, the minimum altitude of the transfer vehicle's operating orbit should be no lower than 1,200 km. Collisions between the TEM and registered objects constituting space debris at any point along the route to and from geostationary orbit can be prevented through the choice of launch date and inter-orbital trajectory for transfer of the TEM and the execution of an evasive manoeuvre using the module's on-board propulsion units. After delivery of the final payload module into geostationary orbit, the TEM is sent into a graveyard orbit located 300 to 500 km above geostationary orbit, thus virtually eliminating the risk of the module's falling to Earth.

Protection of the near-Earth environment is one of the key challenges in ensuring the safety of new-generation space NPS, owing to the significantly higher power capacity of new-generation space NPS (which produce 10 times more power and whose operational life has been increased tenfold), the increased number of space objects in near-Earth space and the increased sensitivity of their equipment.

Requirements have not yet been established relating to levels of pollution in outer space caused by radiation from the reactor or its radioactive products and components. Radiation from the reactor or its components in operational or off mode must be such as to minimize risk to current and future space missions. With regard to types of radiation from the reactor that pose a potential risk of pollution in outer space, it is necessary to take into account positron radiation, which can lead to the formation of artificial radiation belts around Earth. Research must be carried out as a basis for the necessary formulation of requirements relating to acceptable levels of radiation pollution in near-Earth space.

A further challenge is the protection of crews of manned space vehicles in space from the effects of NPS.

Finally, with regard to planned flights to deliver space vehicles to other space objects by means of transport energy modules, there is a need to address the protection of the environment surrounding those bodies from the potential negative effects of NPS.

Russian experts are ready to participate in discussions and the development of solutions regarding this and other possible challenges relating to the safety of space reactor NPS of the twenty-first century.

Conclusion

1. The Russian Federation has established a system for the safe use of space vehicles with NPS that meets international requirements.

2. In accordance with United Nations recommendations, a body of State and space-sector regulations to ensure the safe use of transport energy modules with megawatt-class NPPU is being drawn up.

3. The project to create a TEM with a megawatt-class NPPU is being implemented in accordance with all technical safety measures recommended by the United Nations and prescribed by the relevant regulations of the Russian Federation.

4. While the TEM is being developed, possible new issues relating to the safe use of NPS in space are being examined and identified for further investigation.