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Review of the use of nuclear power sources in space programmes and international cooperation

Working paper submitted by the Russian Federation

I. Discussion and papers on nuclear power sources in outer space

1. In accordance with the work plan of the Scientific and Technical Subcommittee for the period 2003-2006 (A/AC.105/804, annex III), the Subcommittee at its forty-first session, in 2004, heard a number of presentations from representatives of its member States and from representatives of accredited international organizations on space nuclear power sources (NPS) used in spacecraft, in order:

(a) To review information from national and regional space agencies on the content of relevant national (including bilateral and multilateral) space NPS programmes and applications currently planned or in preparation;

(b) To review information from national and regional space agencies on applications enabled or significantly enhanced by space NPS.

2. The following papers were presented to the Scientific and Technical Subcommittee:

(a) Presentation by the Russian Federal Space Agency and the Russian Federal Agency for Atomic Energy on the topic of the Russian space NPS programme;

(b) Presentation by the European Space Agency (ESA), entitled "Space nuclear power sources: concepts and European Space Agency applications for scientific exploration";

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(c) Presentations by the United States National Aeronautics and Space Administration (NASA), entitled "Applications enabled or enhanced by space nuclear power sources" and "Future exploration and nuclear power systems".

3. The papers by the Russian Federation and the United States reflected their accumulated experience in the development, production and exploitation of NPS based on radioisotope sources and fission reactors. They set out the basic parameters and features of future reactor NPS based on nuclear power units (NPU) and nuclear power propulsion units (NPPU) that would meet safety requirements for NPS at every stage, including foreseeable accidents resulting from failure of orbital injection equipment (carrier rockets, upper-stage rockets or spacecraft propulsion units), spacecraft systems or NPS.

4. The papers by national and regional space agencies on NPS use in space programmes confirmed the relevance and validity of space NPS applications.

5. On the basis of those papers, it is also possible:

(a) To engage in a more detailed discussion of the most significant trends in NPS applications and the main features of space NPS safety;

(b) To establish general trends in the use of space NPS;

(c) To consider general aims and problems and develop proposals for international cooperation.

6. The most important feature of international cooperation in enabling space NPS and applying them in space programmes could be to set up joint development, production and exploitation projects.

II. Paper by the Russian Federation

7. The paper presented by the Russian delegation at the forty-first session of the Subcommittee, in 2004, entitled "The main lines of development and uses of nuclear power sources in Russia", was characterized by the following:

(a) It contained no plans to use radioisotope space NPS but focused on using reactor NPS (NPUs and NPPUs);

(b) The required electrical capacity of NPUs and NPPUs for a power system is about 50 kW, while the thermal energy of NPPUs in propulsion systems is of the order of 35 MW; these levels explain why the use of radioisotope space NPS is excluded.

III. Paper by the European Space Agency

8. The ESA paper discussed the limitations of solar-powered spacecraft; ESA participation in United States space programmes to launch the Ulysses and Cassini spacecraft; and a review of the main non-nuclear alternatives.

9. ESA proposed to use radioisotope NPS with plutonium-238 fuel in its space programmes; radioisotope thermoelectric generators (RTG) for on-board electric power and radioisotope heating units (RHU) for on-board thermostatic components

and systems, as well as reactor NPS in the form of NPUs with static conversion systems (thermoelectric, thermionic or thermophotoelectric (TPE)) and dynamic conversion systems (Stirling, Brayton or Rankine cycles) and reactor NPPUs on the basis of rocket propulsion technology.

10. The power consumed on board a spacecraft was estimated to be in the range of 0.02-150 kW, depending on the type of spacecraft and the mission concerned. The main conclusion of ESA was that there were currently no alternatives to space NPS for outer space flights.

IV. Paper by the National Aeronautics and Space Administration

11. The NASA paper considered the possibilities and advantages opened up by the use of space NPS inasmuch as their characteristics and parameters were independent of conditions in space. It presented a review of the application of radioisotope NPS for research into the outer planets of the solar system. It was stressed that, without the use of RHU, which provided individual spacecraft components with heat, the Mars Exploration Rovers, Spirit and Opportunity, would not succeed.

12. For future research into the outer planets of the solar system (Mars, Jupiter, Saturn, Neptune and their satellites), the intention was to use radioisotope and reactor NPS to power the spacecraft’s scientific and communications equipment and the spacecraft itself using an electrojet propulsion system.

13. The intention was to use the following space NPS:

(a) Radioisotope NPS with electrical capacity ranging from a few milliwatts (for miniature spacecraft) to several kilowatts, in the form of RTG and RHU using Stirling cycle and TPE conversion systems;

(b) Reactor NPS with electrical capacity ranging from 20-50 kW to 250 kW, in the form of NPUs based on reactors with liquid-metal or gas coolants and with heat pipes based on the Brayton and Rankine cycle conversion systems and the thermoelectric conversion system.

V. Safety factors involved in the use of nuclear power sources in future space programmes

14. The Russian space programme using reactor NPS is almost exclusively based on future NPUs with thermal emission reactor/converters and NPPUs with reactors based on rocket propulsion technology. The NPUs and NPPUs currently under development fully meet the established specific safety requirements and general technical safety requirements for all regular use by spacecraft personnel and the rocket industry and for all foreseeable accident conditions.

15. The United States space research project Prometheus uses both radioisotope NPS and reactor NPS (NPUs and NPUs plus electrojet propulsion systems).

16. United States space research using radioisotope power systems will be based on a combined RTG and RHU design using plutonium-238 fuel, fully meeting the

safety requirements of radioisotope NPS use, since those systems ensure that the plutonium-238 containers are intact and hermetic at every stage of RTG use on board the spacecraft and under all foreseeable accident conditions.

17. The United States space research programme, while providing for the use of reactor NPS (NPUs and NPPUs plus electrojet propulsion systems), does not contain specific information on the types or parameters of NPS or the means of ensuring their safety. It must be assumed that the technical solutions for the safety issues associated with reactor NPS will be broadly similar in the United States to those adopted in the Russian Federation for NPUs (NPPUs), given the two countries' identical approach to solving the safety issues of both radioisotope and reactor NPS.

18. The ESA space research programme points out the importance of using radioisotope and reactor NPS (NPU or NPPU) but does not specify the actual types of NPS or their parameters or offer solutions to safety issues. That is because ESA member States do not have their own development and production facilities for space NPS.

19. The ESA space research programme on NPS will probably involve its participating in the United States programmes and/or borrowing ready-made space NPS from the United States or the Russian Federation, adapted to ESA conditions for rocket system and spacecraft use. In principle, that opens up distinct possibilities for international cooperation.

VI. Nuclear power source safety standards

20. International cooperation within the Subcommittee and the Committee on the Peaceful Uses of Outer Space is currently focused on the joint development with the International Atomic Energy Agency (IAEA) of safety standards for space radioisotope and reactor NPS with a view to possibly replacing or supplementing the existing principles governing the use of space NPS.

21. Space safety standards of radioisotope and reactor NPS should be based on the most recent IAEA source texts and on the recommendations of the International Commission on Radiological Protection, taking into account national standards and rules, such as the radiation safety standards (MRV-99) or the basic radiation safety sanitary rules (OSPORB-99) currently in force in the Russian Federation.

22. Space NPS safety standards must be maintained by any NPS applications for peaceful purposes:

(a) Radioisotope NPS as sources of power, heat and ionizing radiation;

(b) Reactor NPS as sources of electricity (NPUs and NPPUs for energy systems) and power (NPUs plus electrojet propulsion systems, NPPUs for power systems and rocket propulsion technology) with ejection of the propellant (plasmas of inert gas, hydrogen or hydrogen-bearing coolants) into space.

23. Space NPS safety standards should also apply to the use of reactor and radioisotope space NPS not only in outer space, as stated in the United States and ESA space programmes, but in near-Earth orbits, as is the case with the Russian space programme.

24. It may be that space NPS safety standards should contain specific requirements applying to the use of ionizing radiation sources (gamma quants, neutrons or alpha and beta particles) in interplanetary and near-Earth orbital spacecraft (for example, the Mössbauer spectrometer, the gamma spectrometer or soft-landing systems).

25. Such radiation sources are developed for use in terrestrial conditions and, depending on the construction of a spacecraft and the location of the sources on board, they could break up in the event of an accident to a rocket system or spacecraft. That would be accompanied by the ejection of a comparatively insignificant quantity of radioactivity into the environment.

26. At the same time, in the event of a spacecraft with such radiation sources falling onto an inhabited part of the Earth's surface, following a rocket system failure, search and recovery of such sources are essential.

27. Moreover, having such sources on board a spacecraft could cause significant levels of ionizing radiation around the spacecraft and make terrestrial servicing operations for spacecraft and carrier rockets more difficult.