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Use of nuclear power sources in outer space

Workshop on the Use of Nuclear Power Sources in Outer Space: discussion on the safety of nuclear power sources in outer space

Paper submitted by China**

I. Introduction

1. Since the successful launch of the Chang'e 1 lunar probe in October 2007, China has continued to accelerate its exploration of outer space and has made additional progress in terms of the format of its explorations and the distances involved. A lunar probe, scheduled to be launched in 2013, will carry landing gear and a surveying device to enable it to land on the Moon and study the Moon's surface. As space technology continues to progress, China will explore deeper into space, providing that conditions are suitable, in order to increase man's understanding of outer space.

2. The main issue to be considered in outer space exploration is which power source a spacecraft should use. The distances involved in the exploration of planets located far from Earth lead to a marked decrease in solar constants. Solar-powered technology is therefore not suitable for supporting a mission of that kind. Nuclear power sources are consequently a logical alternative, given present technological conditions. Currently, isotope batteries and reactors are the main nuclear power sources used in space. The nuclides used are Plutonium-238 (Pu-238) and Plutonium-235 (Pu-235). The former is radioactive in its own right, while the

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latter's reactive yields are radioactive. It is vital to study the safety of those nuclides in order to protect people and the environment.

3. The international community has been engaged in space exploration and the use of nuclear power for over 40 years. Nuclear power sources have been used both in near-Earth orbits and in outer space. Space nuclear power sources are essential to outer space exploration as they enable the exploration of cosmic bodies located in areas of the solar system beyond Jupiter. They are also paramount for minimizing the safety risks associated with such power sources both on Earth and in space.

4. In view of those considerations, the Office of Outer Space Affairs of the Secretariat and the International Atomic Energy Agency (IAEA) jointly published the Safety Framework for Nuclear Power Source Applications in Outer Space (A/AC.105/934) in 2009. The document contains guidance on the safe use of nuclear power sources in outer space by the international community and provides administrative and technical suggestions on how countries can develop space nuclear power sources in a safe manner.

II. The use of nuclear power sources in outer space

5. In the soft-landing mission of the lunar exploration project currently being carried out by China, Pu-238-based isotope power sources are used to enable both the landing gear and the surveying device to function in night-time temperatures on the Moon.

III. Analysis of the potential for using nuclear power sources in outer space

6. Currently, the main power sources that can be used on spacecraft are chemical, solar and nuclear energy. The main types of nuclear energy used to generate electricity are radioisotope and reactor nuclear power sources. The size of the opening mechanism and the configuration of the solar or nuclear power device have a direct impact on the size and dynamic characteristics of the space vehicle system. The selection of a suitable power source helps reduce the overall size of the spacecraft and the complexity of the design of the attitude and temperature controls and structural configuration.

7. In the past, recoverable Earth observation satellites tended to use chemical power sources, but such satellites would not spend more than a month in orbit.

8. Solar energy, in the form of solar battery panels, is currently the power source most commonly used in space. The use of solar-powered systems with moderate conversion efficiency in relation to output efficiency is highly developed. Their mass-power ratio and area-power ratio have both reached relatively advanced technological levels.

9. As power requirements increase, so do the requirements for the standard solar wings used in solar-powered systems and the technical complexity of the system for locking the opening mechanism in place. The structure also needs to be reinforced to ensure that it is sufficiently rigid. Structural reinforcement tends to cause a

significant increase in the total mass of the power source system. Once the power requirements for a spacecraft reach a certain level, the total mass and size of the solar-powered system required pose serious technical challenges for the systematic design and manufacture of the flight mission and spacecraft. It thus becomes necessary to find a new power source to increase the efficiency of the whole system.

10. As a spacecraft increases its distance from the Sun, the advantage of using a nuclear power source over a solar power source in outer space becomes increasingly clear. Analysis has shown that solar battery units, once they have reached a distance of five astronomical units from the Sun, decrease in efficiency to a level that is no longer acceptable (and, theoretically, the solar constant at that distance also decreases to 1/25 of the reference value close to the Earth). That phenomenon makes it a priority to use space nuclear power sources when sending spacecraft to Jupiter and other more distant planets in the solar system.

11. The above-mentioned factors demonstrate that space nuclear power sources are the logical choice for the exploration of planets located at greater distances from Earth than Jupiter. The exploration of space, and outer space in particular, needs to opt for space nuclear power sources in view of the fact that solar power is not available, owing to the effects of natural conditions such as darkness and the fact that chemical power sources are insufficient to meet requirements.

IV. Understanding the safety aspects of nuclear power sources in outer space

12. The presence of radioactive materials or nuclear fuels in space nuclear power sources and any accidents caused by them pose a danger to people and the Earth's biosphere. The public is therefore concerned about the safety implications of nuclear power sources in outer space.

13. A number of nuclear accidents have taken place throughout the world in the past few years. Accidents at nuclear power plants include the Three Mile Island nuclear accident in 1979, the Chernobyl nuclear accident in 1986 and the accident at Fukushima in 2011. Accidents involving nuclear reactors in outer space re-entering the Earth's atmosphere include the crash of the RORSAT nuclear power source into the Pacific Ocean to the north of Japan following its failed launch in 1973, the re-entry of a COSMOS satellite into the atmosphere over north-west Canada in 1978, which scattered radioactive debris over an area covering 100,000 km^2, and the crash of a COSMOS satellite into the Atlantic Ocean upon re-entry in 1983. All those accidents became the subject of public concern and debate and led to widespread concern about nuclear safety.

14. Nuclear power sources have been used in space for over 40 years and have powered a range of spacecraft, from ocean observation satellites on lower-Earth orbits to those designed to explore the planets on the outer edges of the solar system. The majority of the spacecraft completed their missions successfully and met the design requirements and thus did not release radioactive pollution into the environment in which they were operating. The safety measures adopted for those spacecraft were therefore feasible and effective and can serve as reference points for the use of nuclear power sources in outer space in the future.

15. For the foreseeable future, nuclear power sources will become the essential technological solution for powering spacecraft designed to explore outer space. However, more attention must be paid to nuclear safety in outer space so that safety considerations are fully taken into account in the design and use of space nuclear power sources. Safety issues must be considered at all stages: the nuclear power source, spacecraft, launch system, design of the flight mission and flight control. Studies must be conducted on the control and technology aspects of nuclear protection and accident policies in order to increase safety capacity, identify measures to deal with problems and find appropriate solutions as part of efforts to reduce safety risks and potential accidents in the use of nuclear power sources.

V. Safe use of nuclear power sources in outer space

16. Space nuclear power sources are essential technological components for supporting missions to explore outer space and have a role to play in enhancing man's understanding and exploration of the universe. As nuclear power sources are brought into use in outer space, it is also vital to take measures to limit injury and damage to people and their environments to levels that are acceptable, even in the worst-case scenario.

17. In order to further develop nuclear technology for use in outer space, it is useful to draw on the successful experience of those countries that have launched nuclear power sources into space and to learn from past accidents so as to ensure nuclear safety and radiation protection. As far as policy measures and administrative checks are concerned, a regime for the design, construction and operation of space nuclear power sources should be established at the national level to regulate nuclear activities in space, develop technologies to ensure the safety of nuclear power sources and radiation protection, analyse the possible consequences of a failure of a nuclear power source in outer space, conduct thorough risk assessments and develop policies for dealing with accidents to reduce risks to an acceptable level.

A. Safety assessment and control

18. The safety of a nuclear power source for use in space is assessed throughout a project, beginning with the decision to carry out the project and continuing during the programme design, research and development, construction and launch stages. A safeguards and emergency plan report for the nuclear power unit forms part of the assessment of the safety of the flight mission. The report, which is a requirement for evaluating whether a project can go ahead, is submitted to a review group. Once adopted by the group, it is presented to the competent State administrative agency for approval. The project may only proceed to the development stage on the basis of that approval.

19. The standards and regulations for safety assessments refer to and draw on the work of the State in relevant areas. The safety standards for space nuclear power sources are divided into a number of sections and cover all areas relating to nuclear safety in space. They include radiation safety and occupational health certificates and requirements relating to staff qualifications, transport, storage, protection, retirement and emergency measures.

B. Safety control of nuclear power sources in outer space

20. Safety control of nuclear power sources in outer space is divided into four parts, namely the start-up of the nuclear power sources, operation control, disposal at the end-of-service phase and safeguards.

21. In China, responsibility for the safety of a nuclear power source in outer space lies mainly with the manufacturer. The developer of the nuclear power source, the developer of the space vehicle and the authority that manages the launch site also have their own responsibilities in relation to safety control.

1. Start-up of the nuclear power source

22. The start-up and operation of the space reactor only commence after the spacecraft enters the safety orbit. The reactor remains shut down until entry into orbit. An outer space probe fitted with a nuclear device is also present in the safety orbit. The flight path does not include a return to Earth, nor does the spacecraft re-enter the Earth's orbit during the leveraging flight.

2. Flight control

23. When the space nuclear power source is in normal operation mode, the amount of radiation released from the power source into the spacecraft must not exceed the levels set by the State and must not have any marked impact on the space environment in which the spacecraft is operating, beyond a specified period of time.

24. The design of the flight path of a spacecraft fitted with a nuclear power source must not include a return to Earth. Payload stability should be maximized in order to help minimize the probability of the spacecraft's accidental re-entry. If an accidental re-entry occurs, the nuclear power source must be designed in such a way that it remains undamaged.

3. Disposal at the end-of-service phase

25. Once a spacecraft with a nuclear power source on a lower-Earth orbit reaches the end-of-service phase, it is sent into a special orbit for disused spacecraft. Nuclear-powered spacecraft operating in outer space must also follow a clear plan for safe disposal.

4. Safeguards

26. The design of nuclear power sources for use in space incorporates safety specifications. As far as the nuclear power source on the spacecraft is concerned, the container used for the power source on Earth is specially designed to help identification and specially designed signs are used on the power source to help ensure safety and facilitate identification. Strict measures are also adopted to control the nuclear devices and materials and to protect them from theft, removal, loss or damage.

C. Technology and relevant work on safeguarding nuclear power sources in outer space

27. The reliability of nuclear power sources should be increased to prevent accidents. Important measures to protect nuclear power sources should also be adopted to ensure the safety of the environment and the spacecraft.

28. At the programme design stage, relevant nuclear safety requirements are added to the functions and performance requirements and the resulting design is reviewed and evaluated.

29. At the prototype stage, special tests are carried out to assess the safety of the space nuclear power sources, in addition to routine environmental tests. They should include assessments of a power source's response to heavy vibration and its resistance to heat, burning, pressure, impact and corrosion. Once the tests have been completed, the results are reviewed and evaluated.

30. At the stage when the product is finalized, and in addition to the tests and experiments conducted on the spacecraft as a whole, tests are also carried out to assess the safety of the nuclear power source. The results are reviewed and evaluated.

VI. Conclusion

31. As regards the safety of nuclear power sources in outer space, China takes a similar view to that contained in the Safety Framework.

32. When it comes to nuclear power sources in outer space, special attention should be paid to technology relating to safety and radiation protection. The safety of the nuclear power sources in outer space should be taken into account in the design of the power source. Safeguards should be put in place and tested in the development process. Relatively accurate risk assessments of nuclear power sources in outer space can be made on the basis of the technology used for conducting risk assessments of civilian nuclear facilities in China. All possible measures should be adopted in accordance with accident plans in order to minimize the consequences of a potential accident.

33. Space nuclear power sources are an essential technological development that facilitate the exploration of space and the universe. However, they also pose a threat to the Earth's biosphere. As nuclear power for use in space is developed, China is committed to supporting the efforts of the Office for Outer Space Affairs and IAEA relating to the safety of space nuclear power sources and is convinced that the safety of such sources is a key issue in the development of space nuclear power technologies.

34. China appeals to countries across the world to strengthen their research and cooperation in developing technologies that ensure the safety of space nuclear power sources in order to increase the safety and use of such technologies, remove any uncertainty about the safety of space nuclear power sources and ensure adequate protection for people and the environment, while also ensuring that the benefits of those new and advanced technologies are widely enjoyed.