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Use of nuclear power sources in outer space

Defining the organizational structure that implements a space nuclear power source mission application**

Paper submitted by the United States of America

Summary

Recent work by the Scientific and Technical Subcommittee of the Committee on the Peaceful Uses of Outer Space in conjunction with the International Atomic Energy Agency has provided a foundational model safety framework that provides governmental, management and technical guidance for establishing national and international intergovernmental safety frameworks. That guidance, while top level, provides both "common ground" for facilitating the development of the organizational structure of a multilateral mission and a benchmark against which the effectiveness of proposed mission-specific organizational structures and processes can be measured.

I. Introduction

1. In addition to the United States of America, and another member State with decades of experience with space nuclear power source (NPS) applications, at least two member States of the Committee and an international intergovernmental organization have embarked on developing space NPS and/or space NPS

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applications. During that process, all have indicated their plans to implement the Safety Framework for Nuclear Power Source Applications in Outer Space,[1] which was jointly developed and agreed to by the International Atomic Energy Agency (IAEA) and the Scientific and Technical Subcommittee of the Committee on the Peaceful Uses of Outer Space in 2009. The United States, which strongly supports the Safety Framework, has already implemented it in its entirety.

2. The Safety Framework provides three types of guidance for member States and international intergovernmental organizations developing space NPS and/or space NPS applications: governmental, management and technical. The governmental guidance focuses on: establishing the policies, requirements and processes for ensuring that safety receives a high priority in the development, operation and end-of-service phases of a space NPS development and/or application; justifying the rationale for the development and/or application of a space NPS; authorizing the launch and operation of a space NPS application; and ensuring the development and implementation of emergency preparedness and response plans as part of any space NPS application. The management guidance focuses on the responsibilities for safety of the organization that conducts a space NPS application and emphasizes that safety should be integrated into the structure and culture of that organization. The technical guidance establishes criteria for adequate competence in nuclear safety, integrating safety into design and development processes, conducting risk assessments and mitigating the potential effects of accidents.

3. In recent sessions of the Subcommittee, certain elements of the governmental and management guidelines of the Safety Framework have been identified as presenting challenges. One State member indicated that the launch authorization process represents a challenge, as the Safety Framework does not explicitly address the case where the launching State and the State responsible for developing and using the space NPS application differ, or how emergency response and preparedness actions would be coordinated when a space NPS application overflies a country not involved in the application. An international intergovernmental organization has expressed a similar view concerning the organization(s) responsible for emergency preparedness and response plans. That organization has also indicated that, in a mission involving multiple States, defining the organization with the prime responsibility for safety, and allocating responsibilities involving authorizing, approving or conducting the mission represent a challenge.

II. Defining the organization that conducts a space nuclear power source mission: the key to implementing the Safety Framework for multilateral missions

4. All multilateral space missions, regardless of whether they involve joint development and operation of spacecraft systems, subsystems, instruments and/or ground systems, require interface agreements between the participating organizations for effective and safe operation. The point in time in a mission's life cycle at which multilateral participation begins typically determines the extent to which the mission's organizational responsibilities, structure and processes have

[1] A/AC.105/934.

been established. If, for example, multilateral participation commences in the conceptual study phase, all mission participants can actively participate in defining the organizational structures, responsibilities and processes for the mission's development. Alternatively, if multilateral participation occurs late in a mission's development phase, then the new multilateral participant will likely be presented with an already formalized management structure, engineering processes and communication interfaces.

5. The implementation of the Safety Framework, while critical to ensuring safe space NPS applications, does not require the replacement of organizational structures or processes that typically exist for multilateral non-NPS missions. If NPS safety requirements (e.g. the establishment of a nuclear safety culture) exist at the earliest stage of a mission's development, then the definition of the organization that conducts the mission will incorporate NPS safety. Even a multilateral mission that considers adding a space NPS application after the mission's development phase has been initiated would face a challenge similar to adding a spacecraft subsystem or instrument that was not part of the original design. In such a case, engineering and configuration management processes would immediately be available for evaluating the impact of the NPS on the existing design and vice versa. New and changed requirements would be defined and, if necessary, the mission's organizational structure, processes, and participants and their respective responsibilities could be modified.

6. The key point here is that countries and international intergovernmental organizations considering or initiating involvement in space NPS applications should integrate space NPS safety into their existing organizational structures and processes. The existing Safety Framework greatly facilitates that process by identifying the scope of requirements that need to be encompassed.

7. At the highest level, the Safety Framework's safety objective of protecting people and the environment in Earth's biosphere "from potential hazards associated with relevant launch, operation and end-of-service mission phases of space NPS applications" is the focal point for defining safety policies, requirements and processes. The Safety Framework's technical guidance specifies that the technical basis for a mission's authorization and approval processes should be supported by a nuclear safety design, test and analysis capability that is applied to the space NPS, spacecraft, launch system, mission design and flight rules. The Safety Framework also specifies that that capability should be maintained throughout all relevant phases of the mission and should be focused on rigorously defining both NPS normal operating conditions and potential accident scenarios, understanding the consequences of potential accidents, and identifying and assessing any engineering features that could reduce risks to people and the environment.

8. That technical guidance contains requirements and criteria that can be incorporated into existing mission organizational and requirements structures and engineering review processes. To the extent that typical (i.e. non-NPS mission) authorization and approval processes lack the expertise or participation of governmental agencies or officials necessary to adequately address the breadth of potential requirements or issues involved in ensuring a mission's nuclear safety, mission managers should identify organizations with the requisite capabilities that also have a responsibility in the nuclear safety portion of the launch authorization process. In that way, additional participant organizations (i.e. those not normally

associated with mission development and launch), incremental analytical requirements and processes not part of non-NPS missions can be expeditiously identified and integrated with more typical mission organizational structures, requirements and processes.

III. Development, launch and use of a nuclear power source application all involve nuclear power source safety responsibilities

9. In the Safety Framework, it is emphasized that important nuclear safety considerations exist in all elements and phases of a space NPS application:

> The underlying approach to satisfying the safety objective should be to reduce the risks from normal operations and potential accidents to as low a level as is reasonably achievable by establishing comprehensive design and development processes that integrate safety considerations in the context of the entire space NPS application (i.e. space NPS, spacecraft, launch system, mission design and flight rules). Nuclear safety should be considered from the earliest stages of design and development and throughout all mission phases.

10. Both the NPS developer and the NPS application developer have responsibility for optimizing nuclear safety. The NPS developer can engineer inherent design safety features that will both help to keep occupational exposures as low as reasonably achievable during the production and integration of NPS with a spacecraft, and reduce the probability, amount and environmental impact of a potential NPS fuel release. Similarly, the NPS application developer can modify and optimize spacecraft and mission designs and/or integration processes to manage occupational exposures, mitigate or reduce the probability or severity of potential failures that could lead to potential NPS fuel releases, and mitigate or reduce the potential hazards to NPS fuel containment in pre-launch processing, launch or mission accidents. In addition, the NPS application launcher can mitigate or reduce the probability or severity of pre-launch processing or launch accidents that threaten NPS fuel containment by increasing launch vehicle reliability and by adding safety systems and/or flight rules that reduce the probability or severity of potential NPS fuel releases in launch accidents.

IV. Multilateral agreements: governing instruments for allocating safety responsibilities for nuclear power sources

11. Given the potential range of NPS, spacecraft, mission and launch designs and configurations (many of which are unique), determining with confidence the primary threats to NPS fuel containment is not immediately apparent or intuitive. Invariably, the likelihood of making an error increases when assumptions are made by one element of the mission team about another mission element without first verifying the validity of those assumptions with the other team. As a result, all participants in a mission with an NPS application have some level of responsibility for nuclear safety. That characteristic of space NPS missions should be addressed by incorporating nuclear safety considerations into the governing instruments for

multilateral missions. For example, mission participants should explicitly agree to support, as appropriate, the definition and satisfaction of the mission's nuclear safety requirements and criteria that are incorporated into the mission's organizational and requirements structures and engineering review processes.

12. The Safety Framework explicitly encompasses that approach by specifying that for multinational or multiorganizational missions, governing instruments should define clearly the allocation of responsibilities for "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 formal mission launch authorization process; and preparing for and responding to emergencies".

Experiences of the United States in space nuclear power source mission applications involving multilateral contributions

13. While not as complex as potential multilateral missions under consideration by other States members and international intergovernmental organizations, past and current NPS mission applications of the United States involving multinational partners have inherently involved multiple government agencies. While the National Aeronautics and Space Administration (NASA) is responsible for the spacecraft and mission, the Department of Energy provides the NPS, the Department of Defense controls the launch vehicle safety design and launch range, and the Environmental Protection Agency would oversee clean-up activities in the event of an accident that releases NPS fuel.

14. While each of those government agencies is independent of each other, they work closely with each other for the purposes of mission success as a single organization, using formally established requirements and processes. For example, in the design and development phase of the mission, NASA, the Department of Energy and the Department of Defense all participate in ground operations and mission integration working groups that are formally integrated into the mission's organizational and engineering review and approval structure and processes. Additionally, all four agencies cooperate with each other as part of an ad hoc inter-agency nuclear safety review panel that evaluates the mission's nuclear safety for an incremental added component — unique to missions involving NPS — of the standard non-NPS launch authorization process.

15. In all cases to date, the international partners on NPS missions of the United States have contributed spacecraft subsystems, components and/or science instruments built to requirements controlled by interface control documents. Those interface control documents were subject to definition, review and approval processes that ensured that the international contributions did not create a credible or significant accident initiation or NPS containment threat under normal or accident conditions. As a result, Unites States launch authorization processes for missions involving NPS have not needed to directly involve international partners in launch nuclear safety analyses or approval processes. Further, because standard engineering review processes ensure that no credible threat to NPS containment has been presented by the foreign partner's contribution, the United States has been able

to effectively indemnify foreign contributors against launch accidents involving space NPS fuel releases.

V. Building on non-nuclear power source mission infrastructure: the key to effective implementation of space nuclear power source safety

16. The history of the space NPS applications of the United States, which spans over 50 years, has demonstrated that an effective nuclear safety framework can be implemented by using and augmenting existing non-NPS organizational structures, requirements and processes.

17. Space NPS missions in the United States have been conducted only about once or twice a decade. At such a low rate, compared with non-NPS missions, it would be extremely difficult and expensive to build and maintain an effective infrastructure for NPS missions separate from that for non-NPS missions.

18. As a result, the United States has built its NPS mission infrastructure in specific areas, but primarily as augmented aspects to the existing non-NPS mission infrastructure. In the context of the Safety Framework, for example, the United States does not change the basic organization of a mission's infrastructure because the mission involves an NPS application. Instead, the technical capabilities are augmented in specific areas to adequately inform design trades and conduct nuclear safety analysis, building upon existing capabilities.

19. For example, launch system reliability and failure effects analysis and modelling delve further into the physical environments created by and the sequence of potential threats to NPS containment resulting from a launch accident. The environmental impacts of releases of radioactive material are assessed using the same meteorological databases and, in some cases, highly similar models for understanding the impacts of accidents involving large-scale accidental releases of launch vehicle propellants. NPS contingency plans follow standard protocols for responding to any large accident that would potentially involve multiple agencies and levels of government.[2]

20. Similarly, mission contingency operations rely on existing non-NPS launch accident contingency response plans, communication systems, operations protocols etc. as the starting point for addressing any mission-unique requirement posed by having an NPS mission application. NPS-specific safety reviews and approvals are handled as incremental requirements for standard mission approvals. For example, while the nuclear safety review and approval process culminates with a decision from the Executive Office of the President of the United States, that decision is limited to the mission's nuclear safety. As such, it is simply an additional "gate" that the mission must pass through prior to entering the standard launch safety and approval process at the launch site.

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[2] For further information, see document A/AC.105/C.1/L.314, entitled "Workshop on the Use of Nuclear Power Sources in Outer Space: United States preparedness and response activities for space exploration missions involving nuclear power sources".

VI. Conclusion

21. Any multilateral mission involving different contributors for the launch system, the spacecraft and/or the power system — regardless of whether NPS are used — requires agreed-to configuration management, interface control and engineering review processes for its design, development, assembly, test, launch and operation. Those standard processes ensure protection of mission hardware and personnel and the public when hazardous materials such as propellants are involved. Mission planners can and should use those existing processes as the starting point for addressing additional requirements arising from the use of NPS.