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EVOLUTION OF THE SPACE NUCLEAR LAUNCH SAFETY REVIEW PROCESS

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Space nuclear power—and in particular radioisotope power systems (RPSs)—serve a niche class of deep space missions: long-duration missions that travel to areas where solar flux is too low or where the environmental conditions are too harsh for solar power to provide sufficient power levels. When certain missions do not have a nuclear power option available, science objectives get re-scoped, transmission of data back to earth is often slower, and the overall return on investment may be compromised. Yet in the past 15 years, the United States has launched historically fewer RPSs. Among other challenges, users of RPSs face a lengthy and costly launch certification review process unlike safety review processes for other aspects of launch.

In order to better understand the RPS launch certification process, this paper traces the evolution of the legal, regulatory, policy frameworks that drives RPS certification via literature review and expert interviews. Documents reviewed include the Presidential Directive/National Security Council Memorandum 25, among others. To the extent possible, we consider the original intent of the document, the effect of the document on the system initially, and its current impact on the system.

With an historic context of legal, regulatory and policy documents, we examine how the implementation of the process has evolved and in what ways. We look at reasons for change in the process, how those changes compare to the language of pertinent legal and policy documents, how, if it all, the changes affected the missions, and what, if any, value-added was brought on by the changes. We then consider potential ways forward including: laws, regulations, and policy pieces that can be clarified or changed in order to better support the system or ways to clarify best practices to foster a more efficient but equally robust system.

I. LEGAL, REGULATORY, AND POLICY EVOLUTION

The founding of the space nuclear safety launch process began in 1961 with President Kennedy's National Security Advisor, McGeorge Bundy, issued National Security Action Memorandum No. 50 (NSAM 50). NSAM50 states that the "President desires to reserve to himself all first official announcements covering the launching into space of systems involving nuclear power in any form" (Bundy 1961).

NSAM 50 was supplanted by Presidential Directive/National Security Council Memorandum No. 25 (PD/NSC-25) in 1977 during the Carter Administration which laid out a more detailed procedure for the required review process prior to nuclear space launches. Updates to PD/NSC-25 followed in 1995 and 1996. PD/NSC-25 includes a requirement from an environmental impact statement (EIS) a process which is mandated by the National Environmental Policy Act of 1969 (NEPA, 42 U.S.C. § 4321 et seq.). NEPA requires that all federal agencies, including NASA, must evaluate and report the effects on the quality of the human environment of any significant agency action in the EIS. Per NEPA, an EIS is required for a wide variety of activities, including launch of radioisotope material. This process is well-defined and has not changed significantly.

Additional guiding documents include Space Policy from the Executive Office of the President (EOP) such as the 2010 National Space Policy. Though this is one of the more recent documents released pertaining to the nuclear launch safety review process, it primarily echoes past documents and practices.

Most recently, in August 2017, the Office of Nuclear Energy (NE) within DOE released a memo detailing the safety analysis plan for Mars 2020, which will use one RTG, following an internal agency review on current practices. The memo (which from here on will be referenced as "2017 DOE Memo") announced that instead of a full SAR, a review on the differences between Mars 2020 and Mars Science Laboratory (MSL), which was launched in 2011, would be conducted. These differences would then be analyzed to determine safety and impact implications.

On the international level, the International Atomic Energy Administration (IAEA) also has guidance for countries launching and handling radioisotope material. This guidance has evolved over time though it is unclear if US law adequately reflects these changes from the international community.

II. EVOLUTION OF IMPLEMENTATION

The safety review for RPS missions involves three separate reviews: (1) the National Environmental Protection Act (NEPA) process which results in an Environmental Impact Statement (EIS), (2) the DOE safety process which results in a Safety Analysis Review

(SAR), and (3) the launch approval process which results in a Safety Evaluation Report (SER) and ultimately launch approval or disapproval (See Fig. 1).

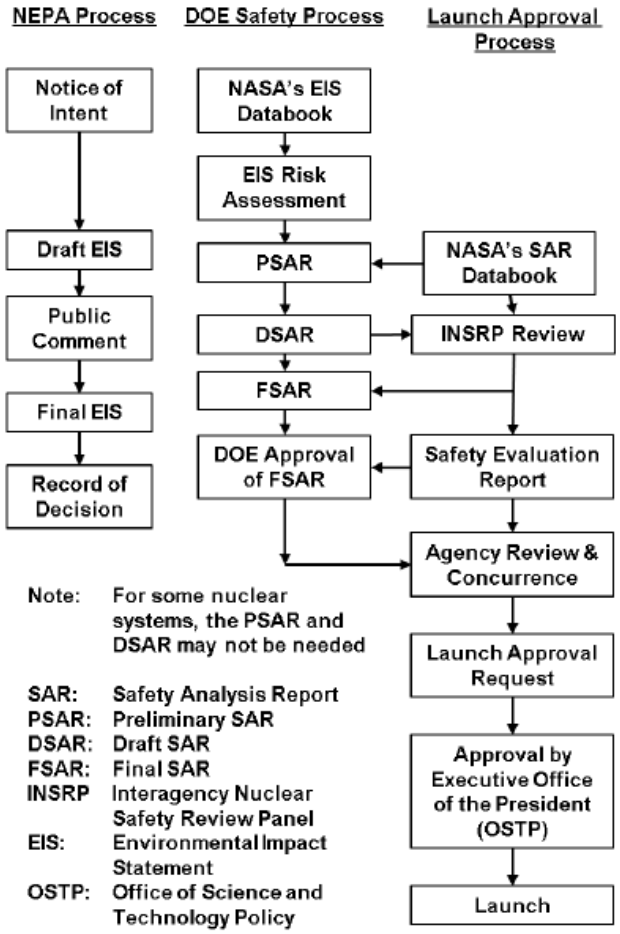

Fig. 1. Overview of Nuclear Launch Safety Review[1]

The three review processes are completed for all missions containing radioactive material as defined by the IAEA Regulations for the Safe Transport of Radioactive Material, Section IV. Via current regulations, RPSs such as MMRTGs which contain 4.8 kg of HS-PuO2 as well as RHUs, which contain about 2.7 g of HS-PuO2 must go through the same trifold review process.

Timelines for the whole review process (including the EIS, SAR, and SER) vary but on average takes a total of 6.5 years. The various lengths of each of the three reviews varies, though for the past four missions, the DOE safety review process takes the longest (Figure 2).

The NEPA process that results in the EIS is completed first, around the Critical Decision Point, and is considered a more notional risk assessment. The EIS also includes a Nuclear Risk Assessment (NRA), prepared by DOE. In total, the process takes from 4 to 8 years to complete. The review process for each of the four past missions has varied in part due to the varied analyses conducted for each mission.

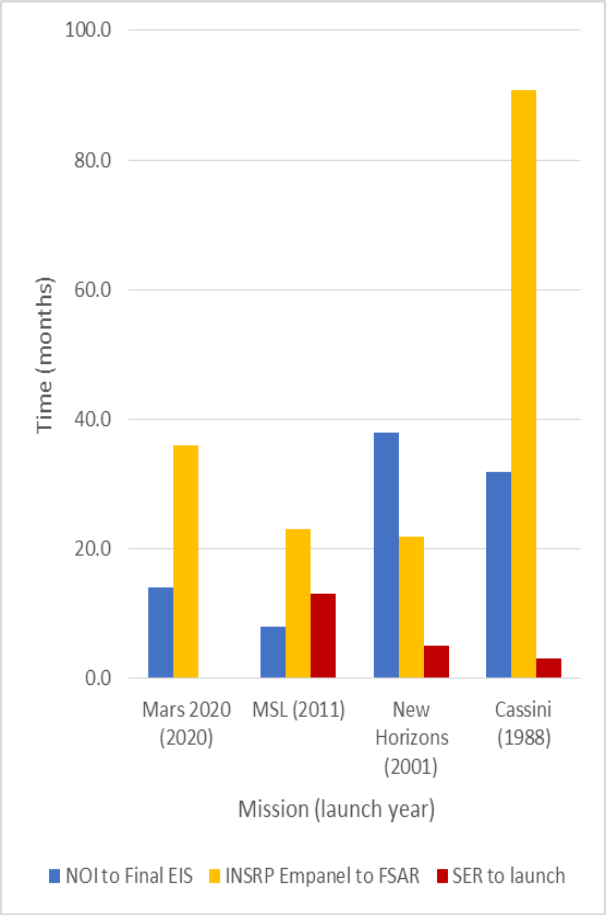

Fig. 2. Review Process Duration for Past Four RPS Missions

The Cassini mission was one of the first missions to do a full-blown safety analysis as the process is known today. Previously, missions underwent safety analyses but the process was executed more "crudely." The shift to move towards a more rigorous process was in part driven by increased technical and computational capabilities. As a part of the safety review process for Cassini, a suit of analysis tools was developed to understand how various worst-case risk scenarios, such as explosions, reentry, and impact, would affect RTGs and the probabilities of an accident. Additionally, codes developed looked at dispersal of radioisotope particles in the atmosphere, if they were to be released from a compromised from an RTG.

For missions following Cassini, INSRP is provided with the opportunity to provide comment on analysis and ask for additional analysis. Because legal and regulatory documents do not include specifics on the types of analyses that must be conducted, analyses for the process, particularly those leading up to the SAR, are virtually

unbounded. Past participants in the process have said that the analyses typically end when time and money run out.

Additionally, the legal and regulatory framework of INSRP is not well defined. Thus the role and function of INSRP has grown and evolved over time. In particular, the INSRP has currently has six working groups and participation from four other agencies in addition to NASA, DOE, and OSTP. Each working group has one to ten members and meet on an ad hoc basis. The INSRP has the ability to both review analyses conducted and ask for additional analyses. Again, because the review process is unbounded, the unwritten practice is that if INSRP asks for additional analyses, that work must be conducted—particularly because the INSRP gives a final recommendation to OSTP.

With each mission, there is a sense of needing to meet or exceed the standards of the previous mission. This means that when new analyses are added for one mission, they are inherently added to each of the proceeding mission reviews. Thus, the SAR and INSRP review process has grown over the years.

II. POLICY CONSIDERATIONS

Safety is immensely important and no revision to the review process—whether it be in legal and policy documentation or institutional practices—should ever compromise safety. This section looks at policy considerations that could lead to changes that could lead to a more efficient safety review process without compromising the fidelity of and confidence in safety.

Some degree of flexibility in the review process—as is currently afforded—is appropriate; the process should exist such that analyses can be adapted as needed depending on the needs of the mission. The regulatory documents and guidance from EOP remains high level in part for agencies (primarily NASA and DOE) to implement as they see fit. However, it is still possible to maintain an appropriate level of flexibility while bounding safety analyses. Such bounds would need to be set by the relevant parties including NASA, DOE, and OSTP, who is ultimately tasked with authorizing the launch. Setting bounds would

Additional policy considerations include reflecting on the nuanced role of each of the three prongs of the review process: the EIS, the SAR, and the SER. It is unclear if each of these three portions offers added value to understanding the safety and risks associated with launching a radioisotope mission. For example, the analyses between the EIS and SAR are similar and may be unnecessarily redundant. In particular for the SAR, the role of INSRP is poorly defined and their active involvement in the process may be unnecessarily burdensome. Decisions-makers need to consider the value of having interagency participation from people who are not directly involved in agencies representing the mission or RTG and plutonium-238 production—in other words, the participation of agencies outside of NASA and DOE. Additionally, decision-makers and relevant agencies should consider the need to have an active INSRP that is allowed to ask for additional analyses and that essentially sets the standards for accepted risk. It may be more valuable to have an INSRP that serves in a purely reviewing function.

III. CONCLUSION

Legal, regulatory, and policy documents guiding the space nuclear launch safety review process have evolved over time. However, with the exception of the 2017 DOE Memo, changes to the documents have had little functional effect on the review process. In fact, the wording in legislation, documentation from EOP, and agency-level policy remains high level and without specifics on the execution of the process.

In contrast, the review process, particularly the SAR portion, has changed for the past several missions. The change, then, is not rooted in regulatory or legal shifts but instead in an institutional cultural desire to as much analysis as resources can support. There is also a cultural mentality of not wanting to accept additional risk as compared to previous mission; in other words, the previous mission serves as a minimum bar for safety standards. This inevitably leads to an ever-growing review process.

This paper provides options that may help bound the process such that the safety review and analyses are appropriately rigorous without becoming unnecessarily burdensome.

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