POLICY ISSUE
(Information)

July 22, 2024 SECY-24-0062

FOR: The Commissioners

FROM: Raymond V. Furstenau
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SUBJECT: RISK-INFORMED METHODOLOGY FOR A FUTURE TRANSPORTABLE TRISO-BASED MICRO-REACTOR PACKAGE APPLICATION

PURPOSE:

The purpose of this paper is to inform the Commission of the U.S. Nuclear Regulatory Commission (NRC) staff's review and endorsement of a risk-informed methodology for a potential U.S. Department of Defense (DoD) transportable micro-reactors package application.

SUMMARY:

The NRC staff has determined that a risk-informed methodology is appropriate for use in developing the safety basis for a Title 10 of the *Code of Federal Regulations* (CFR) Part 71 "Packaging and Transportation of Radioactive Material," application for a transportable micro-reactor similar to the DoD Project Pele design. DoD's Strategic Capabilities Office (SCO) tasked Pacific Northwest National Laboratory (PNNL) with developing the methodology to support potential exemption requests that may be necessary for demonstrating compliance with NRC's transportation regulations. The staff concluded that the risk-informed methodology is acceptable for incorporation in a potential package application for future TRISO-based DoD transportable micro-reactors.[1] The discussion below provides an overview of the methodology, including how it could inform future exemption requests in package applications.

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1 The terms "future DoD reactors" or "future DoD transportable micro-reactors" denote any DoD transportable micro-reactor that is TRISO-based but may differ from the Project Pele demonstration reactor design.

BACKGROUND:

The SCO in the DoD is developing a single, demonstration transportable micro-reactor[2], termed Project Pele. SCO planned to demonstrate that its Project Pele transportable micro-reactor design could meet the NRC's regulations for transportation packages in 10 CFR Part 71. However, based on the design requirements for Project Pele, SCO determined that the application for the transportation package would likely need to include exemption requests from the dose rate and containment criteria after evaluation of the tests for hypothetical accident conditions in 10 CFR Part 71, "Packaging and Transportation of Radioactive Material." [3] Consequently, SCO tasked PNNL with developing a risk-informed methodology based on the characteristics of the Project Pele transportable micro-reactor[4] to be used in developing the safety basis for a package application to support the exemption requests.

Based on its tasking, PNNL provided the NRC with both: (1) the risk-informed methodology and (2) a numerical demonstration of how the risk-informed methodology could be implemented (demonstration probabilistic risk assessment (PRA)). The risk-informed methodology consists of the frequency-consequence (F-C) plots in Figures 4.7 and 4.8 in the PNNL document (Agencywide Documents Access and Management System (ADAMS) Accession No. ML23268A331), and the steps to develop the transportation PRA. The numerical demonstration includes the values and assumptions that PNNL used to develop the transportation PRA.[5]

SCO subsequently stated that it was discontinuing work on the Project Pele transportation application but expressed continued interest in the NRC endorsement of the risk-informed methodology for use in potential future transportation package application (ML24113A069). NRC staff determined that even though PNNL developed the risk-informed methodology using the TRISO-based Project Pele demonstration reactor characteristics, the risk-informed methodology could be applied to any TRISO-based DoD reactor because the methodology does not depend on the specific design of the Project Pele reactor.

DISCUSSION:

The staff reviewed the risk-informed methodology and assessed it against existing Commission regulations and policy. The staff's review focused on whether the risk-informed methodology

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2 While the NRC staff is not proposing a regulatory definition of micro-reactor in this paper, in SECY-20-0093, "Policy and Licensing Considerations Related to Micro-Reactors," dated October 6, 2020 (ML20129J985), the NRC staff described the expected attributes of micro-reactors. Micro-reactors are expected to have thermal power levels on the order of several megawatts to a few tens of megawatts and have small site footprints. They are also expected to have radionuclide inventories that would be about one percent or less of those for typical large light-water reactors and, in the unlikely event of an accident, are anticipated to have lower potential radiological consequences with a correspondingly lower impact on public health and safety. Micro-reactors may also rely on passive systems and inherent characteristics to control reactor power and heat removal.

3 In the enclosure to SECY-24-0008, "Micro-Reactor Licensing and Deployment Considerations: Fuel Loading and Operational Testing at a Factory," dated January 24, 2024 (ML23207A252), a high-level overview of potential package approval pathways for transportable micro-reactors is provided in Item 4, "Transportation of Fueled Factory-Fabricated Modules."

4 For the purposes of the NRC review, the PNNL risk-informed methodology includes the attributes and methods used to develop a PRA for estimating the risks from a transportation accident and the frequency-consequence (F-C) plots used as surrogate guidelines for acceptable levels of risk. The risk-informed methodology does not include the approaches and values used to determine inputs to the transportation PRA as part of the 'demonstration' of how the risk-informed methodology would be implemented.

5 PNNL did not request NRC review of the numerical demonstration. This is because the values and assumptions are only for demonstration of the risk-informed methodology and may not represent the actual values and assumptions that would be used in an exemption request for the micro-reactor module transportation package.

provides an acceptable approach to form the basis of an exemption request as part of a transportation package application. Consistent with PNNL's request, the staff reviewed only the methodology and did not make any assessment of the input data or actual results obtained using that methodology.

Overview of the Risk-Informed Methodology

PNNL developed the risk-informed methodology to support a package application for a future DoD transportable micro-reactor. In the risk-informed methodology, PNNL identified data and information needs that should be included in the application for approval of a Type B fissile (Type BF) package[6] for shipment on a semitrailer of a single-unit transportable micro-reactor module at a maximum frequency of once per year. The risk-informed methodology lays out an approach to develop a PRA that could be used as part of a package application to demonstrate that an exemption request meets the requirements of 10 CFR 71.12.

The risk-informed methodology consists of risk evaluation guidelines (F-C plots) and the systematic process to develop a PRA. The risk evaluation guidelines assess the likelihood of bounding representative accidents and determines their radiological consequences and total effective dose equivalent to workers and the public. Additionally, the risk-informed methodology describes the process to evaluate sensitivity analyses, sources of modeling uncertainty, defense in depth, and safety margins as part of the PRA. The goal of the risk-informed methodology is to inform the package design relative to the risk significance of containment and shielding features and to identify the need for compensatory measures during transportation.

As discussed in the methodology evaluation report in enclosure 1, the risk evaluation guidelines proposed by PNNL are based on existing Department of Energy (DOE) and NRC reports and guidance as well as the International Atomic Energy Agency (IAEA's) Q System. The selection of the likelihood-dose pair limits used by PNNL in the risk-informed methodology as surrogate risk evaluation guidelines aligns with the following: (1) NRC safety goal quantitative health objectives and corresponding proposed quantitative health guidelines (QHGs) from the NRC report "Risk-Informed Decisionmaking for Nuclear Material and Waste Applications," issued February 2008, known as the RIDM report (ML080720238); (2) guidance in NUREG-1520, Revision 2, "Standard Review Plan for Fuel Cycle Facilities License Applications," issued June 2015 (ML15176A258); and (3) guidance in DOE-STD-3009-2014, "Preparation of Nonreactor Nuclear Facility Documented Safety Analysis," issued November 2014 (ML18019A922).

The RIDM report establishes QHGs for activities regulated by the Office of Nuclear Material Safety and Safeguards that can be used in making risk-informed decisions by indicating what level of accident risk should be regarded as "negligible additional risk" to the public, compared to everyday risks to which the average member of the public in the United States is exposed. The QHGs are based on the quantitative health objectives from the 1986 NRC Safety Goal Policy statement (51 FR 30028) developed for the operation of nuclear power plants. The NRC has endorsed similar risk-informed, performance-based approaches to support the licensing of advanced reactor designs in Regulatory Guide 1.233, Revision 0, "Guidance for a Technology-Inclusive, Risk-Informed, and Performance-Based Methodology to Inform the

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6 Type B packages contain a quantity of radioactive material greater than a Type A quantity. The NRC defines a Type A quantity of material and a fissile material package in 10 CFR 71.4.

Licensing Basis and Content of Applications for Licenses, Certifications, and Approvals for Non-Light-Water Reactors," issued June 2020 (ML20091L698).

The references used by PNNL for developing the F-C plots provide a reasonable basis for creating and evaluating proposed risk evaluation guidelines, and several of the references have been developed or approved by the NRC. Further, the risk evaluation guidelines proposed by PNNL are conservative when compared with criteria used for other NRC regulated activities, in that the F-C curves proposed by PNNL are either the same as or lower than other NRC regulated activities. Lower values on the F-C curves result in lower risk. For example, the proposed risk evaluation guidelines are more conservative than the criteria for fuel cycle facilities in NUREG-1520 and for advanced reactor designs in Regulatory Guide 1.233 (which endorses NEI 18-04, Revision 1, "Risk Informed Performance Based Technology Inclusive Guidance for Non-Light Water Reactor Licensing Basis Development," issued August 2019 (ML19241A472)). Regarding risk to the public, the proposed risk evaluation guidelines are more conservative, except for a small portion of the proposed guidelines exceeding the NEI 18-04 risk line, as shown in Figure 4.7 of the PNNL document. Regarding risk to workers, the proposed risk evaluation guidelines are nearly an order of magnitude more conservative than the likelihood criteria in NUREG-1520, to the extent that they overlap, as shown in Figure 4.8 of the PNNL document.

As described in the staff's evaluation of the risk-informed methodology in enclosure 1, the staff finds that the risk-informed methodology outlines an approach that, if followed with appropriate justifications and additional information as discussed in enclosure 1, could be used to form the basis for an exemption request under 10 CFR 71.12.

Regulatory Considerations

A number of regulatory considerations underpinned the staff's review of the risk-informed methodology. For example, after operations, a future DoD transportable micro-reactor module would likely be a Type BF package. Type BF packages are required to be subjected to the tests for hypothetical accident conditions in 10 CFR 71.73, "Hypothetical accident conditions," and then must meet the containment and dose rate criteria in 10 CFR 71.51, "Additional requirements for Type B packages." In addition, Type BF packages must meet the criticality safety requirements specified in 10 CFR 71.55, "General requirements for fissile material packages," and 10 CFR 71.59, "Standards for arrays of fissile material packages."

The risk-informed methodology indicates that it is unlikely that a future DoD transportable micro-reactor designs would be able to meet the NRC's containment and dose rate requirements due to the DoD constraints on the package design (e.g., weight and decay time after shutdown). Specifically, the free-drop test in the hypothetical accident conditions sequence in 10 CFR 71.73(c)(1) requires that the package be evaluated for a 9-meter (30-foot) drop in the most damaging orientation, which could be a top corner over the center of gravity with a corresponding slapdown of the highest point of the package. After evaluation of the free drop, a 1-meter (40-inch) puncture test (again in the most damaging orientation), a 30-minute fully engulfed fire test, and a 0.9-meter (3-foot) immersion test, the package must maintain a dose rate less than 1 rem/hour at 1 meter, no escape of krypton-85 exceeding 10 A_2 in 1 week, and

no loss of other radioactive material exceeding a total amount A_2 in 1 week.[7] Based on the content of the risk-informed methodology, the NRC anticipates that an application for a future DoD transportable micro-reactor package would need to include exemptions from the 30-foot drop test and/or the post-hypothetical accident conditions containment and dose rate criteria.

Using a risk-informed methodology that accounts for likelihood and consequences of postulated accidents (F-C plots and the transport PRA) as a basis for an exemption would be a novel approach for transportation package approval. However, similar aspects to the proposed risk-informed methodology (such as using risk insights to support an exemption from hypothetical accident conditions), have been used to support exemptions for package approval in the past. Further, as discussed above, the proposed F-C plots are consistent with Commission direction in other NRC regulated activities, including risk-informing the licensing basis for non-light-water reactors, as discussed in Regulatory Guide 1.233.

Previously, the NRC staff used risk insights to inform the technical basis for its approval of the Trojan Reactor Vessel Package, Docket No. 71-9271 (ML20155E053). The staff issued the approval using exemptions and a probabilistic safety study (see SECY-98-0231, "Authorization of the Trojan Reactor Vessel Package for One-Time Shipment for Disposal," dated October 2, 1998 (ML23270B931)). In its approval of the Trojan Reactor Vessel Package, the NRC granted exemptions to the Portland General Electric Company for the 30-foot free drop in 10 CFR 71.73(c)(1). The NRC approved the licensee's request to deviate from performing the drop in the most damaging orientation and the height of the free drop test. The staff approved a horizontal, 12-foot (3.66-meter) drop as the only orientation evaluated. In its application for package approval, the Portland General Electric Company demonstrated that the package met the dose rate and containment criteria in 10 CFR 71.51(a)(2) after the 12-foot horizontal drop. In its probabilistic safety study, the Portland General Electric Company demonstrated, and the NRC agreed, that the probability of an accident that would damage the package beyond that evaluated by the applicant for hypothetical accident conditions is less than one in one million. The Portland General Electric Company application included a specified transportation route and modes of shipment, as well as operational and administrative controls to be exercised by the licensee during shipment.

The NRC has not issued exemptions to the dose rate or containment criteria in 10 CFR 71.51(a)(2). If the NRC were to approve an exemption utilizing the methodology, it would be the first time such an approach is used in transportation package approval. As discussed in enclosure 1, the criteria developed for the risk-informed methodology to evaluate package safety (i.e., the F-C plots along with a transport PRA) are consistent with Commission direction and NRC guidance. As discussed in Section 2 of enclosure 1, the F-C plots proposed by PNNL are conservative and consistent with risk-informed approaches for other NRC regulated activities.

The NRC staff's review of the risk-informed methodology did not consider the risks associated with multiple shipments per year along the same route. Thus, the NRC endorsement of the methodology is limited to scenarios with limited transports, as described in the demonstration

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7 As defined in 10 CFR 71.4, "Definitions," the A_2 value "means the maximum activity of radioactive material, other than special form material, LSA, and SCO material, permitted in a Type A package." The radionuclides with smaller A_2 values have a larger hazard because by the Q System radionuclides are normalized based on radiological hazard to a human receptor. The derivation of the A_2 values in Appendix A to 10 CFR Part 71 is determined using the Q System, as discussed in Appendix I to IAEA Specific Safety Guide No. 26, Revision 1, "Advisory Material for the IAEA Regulations for the Safe Transport of Radioactive Material (2018 Edition)," issued June 2022.

PRA. The methodology could potentially be used for alternate transport scenarios, such as multiple shipments per year, with additional considerations and/or justifications.

Stakeholder and Advisory Committee on Reactor Safeguards Engagement

The NRC staff engaged with known commercial vendors that expressed interest in future transportable micro-reactors to determine whether the NRC endorsement of the PNNL methodology could be made generically applicable. As discussed in enclosure 2, no other transportable micro-reactor vendor has indicated an intent to pursue an approach like the PNNL risk-informed methodology; therefore, the staff is not considering the risk-informed methodology as generically applicable for incorporation into applications (i.e., for package approval with an exemption request) other than for future DoD transportable micro-reactors. If transportable micro-reactor vendors signal interest in a similar approach, the staff may revisit whether the risk-informed methodology should be made generally applicable and will engage the Commission, as appropriate.

The staff continues to leverage pre-application engagement activities to gain insights into the transportable micro-reactor developers' package approval plans. Through these engagements, the staff learned that some developers' regulatory approval strategies involve 10 CFR 71.41(c), which authorizes applicants for package approval to use alternate environmental and test conditions to those specified in 10 CFR 71.71 and 10 CFR 71.73, rather than exemptions. Therefore, if a vendor determines that its package cannot meet the otherwise applicable requirements in 10 CFR Part 71 and proposes to use the alternate environmental and test conditions, without exemptions, the applicant for package approval must still meet the dose rate and containment criteria in 10 CFR 71.51(a)(2).

The staff held two meetings with the Advisory Committee on Reactor Safeguards (ACRS), one with the Subcommittee on Radiation Protection on November 17, 2023, and the other with the ACRS Full Committee on December 6, 2023, to discuss the staff's draft endorsement of the PNNL risk-informed methodology (ML23296A083). The ACRS provided a letter containing a summary of the December 6, 2023, meeting (ML23354A012), and ACRS feedback from the meetings is available via the meeting transcripts (ML23352A309 and ML24017A222). The ACRS feedback from these meetings informed the staff's evaluation of the risk-informed methodology, the development of the endorsement, and this SECY paper.

Enclosure 1 reflects the following feedback received from the ACRS:

- Clarified the scope of the risk-informed methodology and differentiated the methodology from the numerical demonstration;
- Updated Section 3.1.1, "Initiating Events," to clarify that a future package should provide all safety functions that affect the package performance;
- Updated Section 3.1.2, "Accident Sequence Analysis (Evaluation of Accident Effects on the Package)," to specify that the package application should include consideration of material degradation;
- Added Section 3.1.3, "Estimating the Likelihood of Accident Scenarios," to include a discussion on estimation of accident frequencies; and

- Updated the language at the end of Section 3 to clarify that the package application should address the potential for cliff edge effects in the PRA.

Next Steps

The staff plans to transmit the enclosed letter and methodology evaluation report to SCO 11 business days after issuance of this information paper. After PNNL publishes a final version of the document, the staff intends to issue a letter to SCO endorsing the risk-informed methodology (e.g., stating that the NRC agrees that the risk-informed methodology is acceptable for inclusion in a package application for a potential future DoD transportable micro-reactor).

The staff will continue its outreach and engagement activities with transportable micro-reactor vendors on package approval plans to assess any potential challenges in meeting regulatory requirements. If, as a result of these interactions, the staff or industry identifies specific needs in meeting the regulatory requirements, the staff will engage the Commission, as appropriate.

CONCLUSION:

The staff determined that the risk-informed methodology conforms with existing Commission regulations and policy. The staff evaluated the technical merits of the risk-informed methodology and determined that it is acceptable for incorporation in a potential future application for package approval for a DoD transportable micro-reactor package.

RESOURCES:

This paper does not address any new commitments or resource implications.

COORDINATION:

The Office of the General Counsel reviewed this Commission paper and has no legal objection.

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Enclosures:
1. Letter and Methodology Evaluation
2. Engagements with Transportable Micro-reactor Vendors on Transport Package Approval

SUBJECT: RISK-INFORMED METHODOLOGY FOR A FUTURE TRANSPORTABLE MICRO-REACTOR PACKAGE APPROVAL DATED: July 22, 2024

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