DEFENSE NUCLEAR FACILITIES SAFETY BOARD
Washington, DC 20004-2901

January 6, 2022

The Honorable Jennifer M. Granholm
Secretary of Energy
US Department of Energy
1000 Independence Avenue, SW
Washington, DC 20585-1000

Dear Secretary Granholm:

The Defense Nuclear Facilities Safety Board (Board) has been following the Department of Energy's (DOE) progress in development of the Surplus Plutonium Disposition (SPD) project at the Savannah River Site (SRS). This major modification to the K-Area Complex facility will provide an important capability to continue the disposition of surplus weapons-grade plutonium at SRS.

The Board has reviewed the design and safety basis documents associated with the project, including those supporting the Critical Decision-1 milestone in October 2019, and identified the need for additional safety analyses related to fire protection and explosion hazards. DOE should address these safety observations as the design matures to ensure the SPD project meets DOE's safety requirements. To this end, the Board is encouraged by recent direction from the National Nuclear Security Administration to the project to update the engineering evaluation for the fire suppression system selection that we received after finalizing the staff report.

The enclosed staff report, provided for your information and use, further describes the Board's safety observations. The Board and its staff will continue to evaluate the facility design as it develops.

Sincerely,

Joyce L. Connery

Joyce L. Connery
Chair

Enclosure

c: Mr. Joe Olencz

DEFENSE NUCLEAR FACILITIES SAFETY BOARD

Staff Report

September 2, 2021

Conceptual Design for the Surplus Plutonium Disposition Project at the Savannah River Site

Summary. The Defense Nuclear Facilities Safety Board's (Board) staff found that the overall safety hazard analysis and control strategy for the Surplus Plutonium Disposition (SPD) project at the Savannah River Site (SRS) was adequate at the Critical Decision (CD)-1 milestone. Notwithstanding this conclusion, the staff noted areas that warrant additional analysis to fully support the safety conclusions presented in the current documentation. Safety issues that have emerged as the design progressed from CD-1 to 60 percent complete include:

- Additional safety analysis needed to support design of the fire suppression system, and
- Analysis needed of hydrogen detonations inside gloveboxes.

The appendix to this report details other elements of the staff review and interaction with the SPD project team that resulted in resolution at the staff-to-staff level.

Background. The SPD project is a major modification to the K-Area Complex, Building 105-K at SRS. The project falls programmatically under the purview of the National Nuclear Security Administration (NNSA) and the assigned federal project director is from NNSA. The project is being installed into an existing facility operated by Savannah River Nuclear Solutions (SRNS) for the Department of Energy's (DOE) Office of Environmental Management.

The SPD project mission is to install three new glovebox lines that will be used to dilute and dispose surplus weapons-grade plutonium. The same process is currently conducted at a smaller scale in a single glovebox at the K-Area Complex. The SPD project is scoped to meet material processing milestones by improving throughput and is intended to improve the safety of the existing process. The safety control set includes safety-class fire suppression, detection, and actuation; building structure; containers; and fire barriers. Safety-significant active confinement ventilation and gloveboxes are also specified. Notably, the project intends to use a clean agent suppressant (Novec® 1230) for its fire suppression system, which will be the first use of a such a system in a safety-class application in the DOE complex.

DOE approved CD-1 for the SPD project in October 2019, which corresponded to approximately 30 percent design completion. Since then, the project has advanced to approximately 60 percent design completion. The staff initially reviewed the documentation supporting the CD-1 milestone, including the safety design strategy, conceptual safety design report, consolidated hazards analysis (CHA), preliminary accident analysis, fire scenario document, associated DOE safety review letters, and relevant supporting safety calculations and

analyses. The staff also reviewed updates to key documents that were finalized after CD-1 approval, including a new revision to the nuclear criticality safety evaluation.

The staff transmitted an agenda with specific safety lines of inquiry to DOE-EM, NNSA, and SRNS personnel on January 25, 2021. SRNS personnel provided the staff with a project overview presentation on March 16, 2021, which was very helpful in supporting subsequent discussions. Project personnel provided written responses to the staff's agenda, along with several updated or new documents, on March 23, 2021. The staff conducted a series of teleconference discussions with project personnel April 13–15, 2021, with subsequent follow-up that culminated in a factual accuracy discussion with the project on July 7, 2021.

Discussion. The following sections document staff observations regarding the SPD conceptual design. In general, these safety observations exhibit the common conclusion that further analysis is warranted to fully support design and safety control decisions.

Additional Safety Analysis Needed for the Design of the Fire Suppression System—The project intends to use a clean agent suppressant system. Such systems are typically used in applications where property, equipment, or nuclear criticality safety concerns make water-based systems less desirable. For example, the K-Area Complex implements an FM-200™ clean agent system. Novec® 1230 suppresses the fire through heat absorption that relies on rapid dispersal of the stored liquid into vapor form in the affected space. The concentration of suppressant is defined relative to the class of fire being extinguished and must be held for a pre-determined duration to ensure no re-flash is possible. Clean agent systems typically have an actuation delay time to allow egress of personnel, although Novec® 1230 is not considered a significant chemical hazard to humans under National Fire Protection Association (NFPA) 2001, *Standard on Clean Agent Fire Extinguishing Systems*, which defines a "no observable adverse effects limit" of 10 percent by volume in air.

The project's fire analysis consists primarily of a scenario development document [22], fire hazards analysis [23], system design description [15], and single failure analysis [24]. Based on review of these documents, the staff identified several safety concerns.

- **Fire Growth Analysis:** The analysis of the fire scenario identifies several expected conditions related to fuel sources, but does not provide sufficient detail regarding how these conditions will contribute to fire growth and potentially impact the system's ability to suppress fires within segregated areas of the facility. This is important because the project plans to use a 57-second delay to accommodate the egress of workers and this duration exceeds a more typical 15- to 30-second delay in other applications for clean agent systems.

- **Single Failure Criteria**: A fire involving combustible liquids may not be extinguished in the event of a single failure in one of the system trains because both trains are needed to achieve the design concentration of suppressant. This is important because the safety-class fire suppression system is required to meet the single point failure criterion specified in DOE Order 420.1C, *Facility Safety*.

- **Hydrogen Fluoride Generation**: The interaction between clean agent suppressants such as Novec® 1230 and flames produces hydrogen fluoride (HF), a toxic chemical. The project did not carry forward HF into the CHA [1] for evaluation. Following the staff's identification of this safety issue, project personnel revised the CHA [25] to list HF as a hazard but concluded evaluation of HF was not required because it is a fire decomposition product, citing Appendix A.2 of DOE Standard 3009-2014, *Preparation of Nonreactor Nuclear Facility Documented Safety Analysis*. The staff concluded that screening out the HF hazard does not ensure that the project will sufficiently consider worker consequences in the design of the facility, including worker egress. The staff also notes that the project must ensure workers are not exposed to toxic levels of gaseous fire suppressant agent or decomposition products as required by Title 10 Code of Federal Regulations (CFR) Part 851, *Worker Safety and Health Program*[1]. There are unique factors with this application warranting consideration, including the relationship between system actuation delay time, detailed egress analysis, and fire growth due to facility-specific fuel sources. Considering that SPD will be the first defense nuclear facility to implement a safety-class clean agent fire suppression system, the project should fully understand, document, and control this hazard as it moves forward in the design process.

Safety Analysis Needed of Hydrogen Detonations Inside Gloveboxes—The potential detonation of hydrogen during the cutting of a 3013 container in a glovebox is not properly analyzed to examine the impact on glovebox integrity and hazards to the facility worker. The project developed a calculation [26] that only analyzes a hydrogen deflagration, assuming all of the hydrogen in the 3013 container is fully released and mixed into the glovebox's air atmosphere and then combusted. Project personnel acknowledged the staff's safety concern and committed to update the calculation to address the potential for hydrogen detonation. As the project revises the calculation, the following may be helpful:

- **Detonation at the Point of Release**: The potential for a hydrogen detonation event should specifically consider ignition at the point of release from the container where the air/hydrogen mixture is at an optimum concentration and the ignition source is sparking from the cutting operation. The calculation should address the potential for the associated shock impact to breach the glovebox barrier or generate shrapnel from the container.

- **Operational Experience Data:** The safety basis for the K-Area Complex's interim surveillance glovebox previously credited a puncturing device to avoid hydrogen detonation events, but recently removed this control, primarily citing operational experience and data reflecting minimal release of hydrogen from 3013 containers. The SPD project has not captured this basis in its documentation for SPD operations.

[1] 10 CFR 851 requires compliance with 29 CFR 1910 Subpart L, Fire Protection, which includes Section 162 covering gaseous agent extinguishing systems.

Conclusion. Based on its review of documentation supporting the CD-1 milestone for the SPD project, the staff found that the overall safety hazard analysis and control strategy for the project at CD-1 was adequate. However, in considering the subsequent advancement of the design from CD-1 to 60 percent complete, the staff noted areas that warrant additional analysis to fully support the conclusions presented in the current revisions of safety-related documentation. These areas include fire protection and explosion hazards. The appendix to this report details other elements of the staff's safety review and interactions with the SPD project team that resulted in resolution of safety issues at the staff-to-staff level.

Appendix A

This appendix to the Defense Nuclear Facilities Safety Board's (Board) staff's report contains additional information and observations related to the Surplus Plutonium Disposition (SPD) project conceptual design. Interaction between the staff and the project team resulted in a common understanding of the project status and staff safety concerns. As a result, project personnel committed to specific actions as the design and safety analysis progresses.

Basis for Screening Chemical Hazards. The project's documentation does not provide a list of the types and quantities of chemicals considered nor the basis for further considering their hazards and the need to elevate controls, a process known as screening. This screening process is required by Department of Energy (DOE) Standard 3009-2014, *Preparation of Nonreactor Nuclear Facility Documented Safety Analysis*, which the project implements. On May 19, 2021, the project provided a follow-up listing of chemicals currently present in Building 105-K, which is assumed to align with the list of chemicals that will be present at SPD, and committed that the chemical screening criteria from Section A.2 of DOE-STD-3009-2014, *Preparation of Nonreactor Nuclear Facility Documented Safety Analysis*, will be applied and included in a subsequent revision of the consolidated hazards analysis (CHA).

Section 5.3.1 of the CHA contains the following statement regarding chemical hazards at the SPD project: "Since hazardous chemical inventories are controlled below the Threshold Quantities, Threshold Planning Quantities, and Reportable Quantities, chemical inventories do not require further analysis (WSRC-SA-2002-00005)." DOE Standard 3009-2014 does not contain any allowance for screening out chemical hazards based on these threshold values.

Safety Basis and Code of Record. The CHA [25], is the primary safety basis document being used to implement changes to the project as the design and safety analysis progress. The initial revision of the conceptual safety design report [5], approved by DOE in May 2018, supported CD-1 approval. However, the project has determined, with DOE concurrence, that this is not a living document and will update it before the issuance of the preliminary documented safety analysis. As a result, there are acknowledged misalignments between the current CHA and the conceptual safety design report that will not be resolved until the preliminary documented safety analysis is completed. While not typical, the staff did not identify any safety concerns with this approach. DOE approved revision 1 of the safety design strategy [4] in April 2019, and this remains the current revision. The Board's staff team reviewed the conceptual safety design report and safety design strategy and concluded that these documents meet the applicable requirements for scope and content as established by DOE Standard 1189-2016, *Integration of Safety into the Design Process*.

The project code of record does not explicitly list DOE Standard 3009-2014. However, this standard is identified in the safety design strategy as the safe harbor to be used for safety basis development, and was confirmed to be applicable by project personnel.

Accident Analysis. The staff reviewed the preliminary accident analysis document [2] supporting CD-1 approval and noted the following potentially non-conservative parameters: For a seismic event with dilute process area fire (Event N2), the unmitigated respirable fraction

and damage ratio parameters selected were 0.1 for impact releases of plutonium oxide from SAVY containers in a glovebox, glovebox holdup, and transuranic waste drums.

- For an explosion in a glovebox during can cutting operations (Event X2), the respirable fraction parameter selected was 0.01 for thermal stress and 0.1 for pressure wave impacts to adjacent containers for plutonium oxide.

The project revised and released updated accident analysis calculations in May 2021, which appear to address these examples of non-conservative parameters. Of interest, while the project is not relying on testing of 3013 containers currently being conducted by Sandia National Laboratories, project personnel plan to evaluate any new information that may come from this testing and assess impact to the project.

Consequence Analysis. For a fire in the packaging room (Event SPD-1-003) area, the collocated worker radiological consequence is incorrectly identified as "Low" vice "Moderate." Project personnel committed to correct this error in the next CHA update. The staff does not anticipate any change to the control set due to safety-related controls already being identified.

3013 Container II/I. Project personnel assumed that zero radioactive material would be released as the result of seismic impact to 3013 containers (i.e., a damage ratio of zero). This means that no material would be released by 3013 containers falling during an earthquake nor would containers be crushed by large objects. The staff questioned the basis for this assumption and project personnel indicated design requirements would preclude seismic II/I challenges to 3013 containers. Project personnel further specified that the facility design description [7] contains a requirement that "SSCs [structures, systems, and components] whose failure could impact the function of higher performance category SSCs shall be supported and anchored for NPH [natural phenomena hazards] loads associated with the higher NDC [NPH Design Category] SSC." This requirement should also flow down to relevant system design descriptions, such as for the fire suppression system, to ensure that no heavy SSCs could fall and impact a 3013 container. The project further determined that some system design descriptions have not adequately included this requirement and intends to update them in the next revision accordingly.

Emergency Response. The project's safety design strategy [4] indicates that interface with systems in the rest of the K-Area complex will be limited, including with the ventilation system and fire-related controls. Project personnel clarified during the factual accuracy review that the SPD fire alarm system will connect to the K-Area Complex fire alarm control panel and annunciator in the K-Area Complex control room. This will allow control room personnel to use the public address system to direct workers to take appropriate protective actions based on the location of the fire.

Analysis of Meteorological Data to Determine Air-Dispersion Factors. Safety analysis requires conservative approaches to the modeling used to determine how radioactive material will disperse in the atmosphere and what will be the potential consequences to workers and the public. A key element of dispersion modeling is site-specific meteorlogical data. DOE Standard 3009-2014, Section 3.2.4.2, requires that five years of representative, recent

meteorological data be used as input to the dispersion model. DOE Handbook 1224-2018, *Hazard and Accident Analysis Handbook*, further defines "recent" as within the past 10 years.

The project's air-dispersion factor calculation [16] used meteorological data from 2002 to 2006 because this data set has been processed into a form suitable for the project's air-dispersion factor analysis. Since more recent five-year meteorological data is available from 2014 to 2018, project personnel compared joint frequency distributions of the wind-direction and wind-speed between the two data sets using a meteorological data processing code known as AXAIR89Q. They concluded that the wind-pattern did not change significantly, and thus the accident analysis did not need to be updated with the newer data.

The staff notes that the corresponding 95th percentile hourly air-dispersion factor values were not explicitly listed in the technical notes [17, 18] for the analysis and that using more recent five-year meteorological data for accident dose calculations would more strictly align with DOE requirements and guidance. Based on discussions with project personnel, this is a broader concern at SRS that requires additional technical resources to resolve.

References

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[3] Savannah River Nuclear Solutions, *Total Effective Dose Factors for Onsite and Offsite Receptors at SRS*, S-CLC-G-00372, Rev. 4, Approved 4/30/2018.

[4] Savannah River Nuclear Solutions, *Safety Design Strategy for K-Area Complex Surplus Plutonium Disposition Project*, SRS-TR-2017-00195, Rev. 1, April 2019.

[5] Savannah River Nuclear Solutions, *Conceptual Safety Design Report for K-Area Complex Surplus Plutonium Disposition Project*, U-CSDR-K-00001, Rev. 0, May 2018.

[6] National Nuclear Security Administration, *Conceptual Design Report for Surplus Plutonium Disposition Project*, G-CDR-K-00007, Rev. 0, October 2019.

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[8] Savannah River Nuclear Solutions, *Project Fire Hazards Analysis for the Surplus Plutonium Disposition Project in the K-Area Complex*, Rev. 2, F-PFHA-K-00012, Approved 4/26/2018.

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[11] Savannah River Nuclear Solutions, *Fire Scenario Document for the Surplus Plutonium Disposition Project in the K-Area Complex*, Rev. 3, F-TRT-K-00027, Approved 5/7/2018.

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[15] Savannah River Nuclear Solutions, *Surplus Plutonium Disposition Project Fire Protection System, System Design Description*, M-SYD-K-00038, Rev. 0, Approved 6/9/2020.

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[19] Savannah River Nuclear Solutions, *Active Confinement Ventilation System, System Design Description*, M-SYD-K-00036, Rev. 1, 9/29/2020.

[20] Savannah River Nuclear Solutions, *Nuclear Criticality Safety Evaluation: Fissile Processing in the K-Area Surplus Plutonium Disposition Project,* N-NCS-K-00082, Rev. 0, 12/18/2019.

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[22] Savannah River Nuclear Solutions, *Fire Scenario Document for the Surplus Plutonium Disposition Project in the K-Area Complex*, Rev. 5, F-TRT-K-00027, Rev. 5, 2/8/2021.

[23] Savannah River Nuclear Solutions, *Project Fire Hazards Analysis for the Surplus Plutonium Disposition Project*, F-PFHA-K-00012, Rev. 3, 10/28/2019.

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