Joyce L. Connery, Chair

Thomas A. Summers, Vice Chair

Jessie H. Roberson

DEFENSE NUCLEAR FACILITIES SAFETY BOARD

Washington, DC 20004-2901

June 15, 2021

The Honorable Jennifer 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 recognizes the Department of Energy's approval of Critical Decision-1 for the Tritium Finishing Facility (TFF) at the Savannah River Site, which marks the completion of the project definition phase and the conceptual design.

The Board has reviewed the design and safety basis documents associated with the Critical Decision-1 milestone and identified observations in several key areas: confinement strategy, hazard and accident analysis, identification and classification of controls, code of record, software quality assurance, and the tracking of open items. The National Nuclear Security Administration should address these observations as the design matures to ensure TFF meets DOE's safety requirements, given the facility's importance to NNSA's safety strategy for the Savannah River Tritium Enterprise.

NNSA cited TFF as the primary long-term solution for improving safety at the Savannah River Tritium Enterprise when responding to Board's Recommendation 2019-2, *Safety of the Savannah River Tritium Facilities*. Because TFF will not address the hazards of credible energetic events at other facilities of the Savannah River Tritium Enterprise, the Board remains concerned with protecting the public and workers around these facilities. In addition, the estimated start-up of TFF is in the 2030s; therefore, it is important for NNSA to identify compensatory measures and improve safety at the operating tritium facilities in the near term.

The enclosed staff report, provided for your information and use, further describes the observations. The Board and its staff will continue to evaluate the facility design as it develops and are planning a focused review when it reaches 30 percent completion, followed by continued oversight at subsequent design milestones and start-up and operations.

Sincerely,

Joyce L. Connery

Joyce L. Connery
Chair

c: Mr. Joe Olencz

DEFENSE NUCLEAR FACILITIES SAFETY BOARD

Staff Report

March 18, 2021

Critical Decision-1 for the Tritium Finishing Facility at the Savannah River Site

Summary. After reviewing the conceptual design and safety basis documentation associated with the Critical Decision-1 (CD-1) milestone for the Savannah River Site's (SRS) Tritium Finishing Facility (TFF), the Defense Nuclear Facilities Safety Board's (Board) staff identified observations in six key areas: confinement strategy, hazard and accident analysis, identification and classification of controls, code of record, software quality assurance, and the tracking of open items. The National Nuclear Security Administration (NNSA) will need to address these observations as the design matures to ensure TFF meets the Department of Energy's (DOE) safety requirements. The staff will continue to monitor the development of the facility's design and plans to reengage with project personnel when the facility design reaches 30 percent completion.

Background. TFF is a planned facility at SRS intended to replace key capabilities currently located in H-Area Old Manufacturing—a 1950s vintage building that does not fully comply with current industry codes and standards. When responding to Recommendation 2019-2, *Safety of the Savannah River Tritium Facilities*, NNSA cited TFF as the primary long-term solution for improving safety at the SRS Tritium Facilities. The overall TFF safety strategy relies on multiple safety class and safety significant structures, systems, and components. This new facility, which is a safety class building structure designed to the natural phenomena hazard design category 3 (NDC-3) criteria and which contains a safety class fire suppression system, would be a considerable improvement over the existing control strategy. The new facility will not address the hazards associated with several credible energetic events at other facilities of the Savannah River Tritium Enterprise, and it will not be operational until the 2030s. As a result, the Board's concerns with protecting the public and workers and responding to a large-scale event around these facilities, as detailed in Recommendation 2019-2, have not been addressed.

The CD-1 package lists four main TFF buildings:

- Building 1—a new Hazard Category (HC)-2 facility—for packaging and shipping, reservoir assessment, reservoir acceptance, assembly, and returned reservoir storage;

- Building 2—a new HC-3 facility—for a metallography laboratory and pre-loading process;

- Building 249-H—an existing non-nuclear facility—for container storage, container reverification, receipt inspection, inert loading, and "transient inventory movement" via a corridor from H-Area New Manufacturing to Building 1; and

- Building 234-7H—an existing HC-2 facility—for relocation of research and development activities and reservoir capabilities currently located in H-Area Old Manufacturing (e.g., relocation of Savannah River National Laboratory functions).

After CD-1 approval, NNSA decided to remove the Building 234-7H scope from the TFF project and advance it as a separate project. In addition, NNSA removed the Building 249-H renovations from the project and decided to pursue an alternative that involves enlarging the new buildings and constructing a new corridor for the transient inventory movement.

The former contractor, Parsons, originally developed the CD-1 documentation for the Tritium Production Capability Project, which was later renamed TFF. NNSA placed the project on hold in 2018 due to funding constraints. In December 2019, NNSA approved the CD-1 milestone, marking the completion of the project definition phase and the conceptual design. The current contractor, Savannah River Nuclear Solutions (SRNS), did not revise the CD-1 documentation before the approval. The Board's staff held a series of teleconferences with DOE and SRNS personnel in October–December 2020 to discuss the CD-1 documentation and current planning for the project.

Discussion. The staff reviewed the safety basis and design documents associated with the CD-1 milestone, i.e., the safety design strategy [1], the conceptual safety design report (CSDR) [2], the conceptual design report [3], and supporting documents. The objective of the review was to understand NNSA's approach to TFF's safety strategy, control selection, and design of key structures, systems, and components; as well as to evaluate NNSA's efforts in early integration of safety into the TFF design.

NNSA indicated that the facility design was only 5 percent complete at the CD-1 milestone. DOE's directives do not prescribe a percentage of the design that must be achieved at the conceptual design phase and acknowledge that a facility design may be anywhere between 0 and 30 percent complete. The staff identified observations in six key areas that must be adequately addressed as the design matures. These observations are as follows:

Confinement Strategy—Confinement ventilation systems using particulate filters are not effective to confine tritium that is released as either a gas or vapor. The TFF confinement strategy relies on safety class robust containers and credits them as an initial condition. The robust containers are credited to provide confinement during normal handling accidents but are not intended to prevent a release during a fire or explosion event. The safety design strategy relies on the safety class building structure to protect the robust containers from impacts [1]. The safety class fire suppression system protects the robust containers from longer-term fire impingement. The CSDR identifies that 20 percent of the material-at-risk (MAR) in robust containers would be impacted and released prior to the activation of the fire suppression system for common cause events, e.g., natural phenomenon hazard events [2].

TFF project personnel elected to use a safety significant ventilation system with an elevated stack release to reduce doses to the co-located worker instead of confining MAR during credible accident scenarios. To reduce the dose consequences for tritium releases, a consolidated hazard analysis for the operating SRS Tritium Facilities identifies an elevated release via a stack or the addition of a room or building-level scrubber or stripper system as a potential improvement to the confinement strategy [4]. During the discussions, SRNS personnel indicated that the size of any scrubber or stripper system would not be practicable based on an informal analysis. SRNS personnel stated that an evaluation of the adequacy of the confinement strategy would be performed during upcoming design activities.

DOE Order 420.1C, *Facility Safety*, requires facilities with uncontained nuclear material to have the means to confine the material during normal and abnormal conditions, up to and including design basis events. There has not been a documented evaluation of the feasibility of alternatives that would meet the DOE Order 420.1C confinement requirements, such as alternatives that would prevent or capture releases. The criteria of DOE Standard 1104, *Review and Approval of Nuclear Facility Safety Basis and Safety Design Basis Documents*, identifies that confirming the adequacy and sufficient conservatism of the approach to meeting the safety design criteria of DOE Order 420.1C, or approved exemptions and equivalencies, are part of CSDR development.

Hazard and Accident Analysis—The preliminary hazard analysis prepared for TFF as part of the CD-1 documentation is based on the hazard analysis for the operating SRS Tritium Facilities [5]. This resulted in transposing similar issues that currently exist onto the new facility. These are as follows:

- The hazard analysis for the existing 217-H vault postulates an impact to the stored material by a gas cylinder during maintenance activities when the vault door is open, which results in significant consequences to the workers. The TFF CSDR also includes this hazard even though it is not applicable for the TFF design [2]. NNSA should consider eliminating this hazard for TFF.

- Similar to the hazard analysis for the operating Tritium Facilities, the preliminary hazard analysis states an external load drop onto the building with significant consequences to the co-located workers will be controlled through a critical lift safety management program. If critical lifts will be routine, this hazard could be eliminated by designing the relevant areas of the building structure to withstand a credible load drop or by preventing critical lifts over the facility rather than relying on administrative controls. This use of an engineered control would be consistent with the hierarchy of controls outlined in DOE Standard 3009, *Preparation of Nonreactor Nuclear Facility Documented Safety Analysis*. If a need arises to perform a critical lift that exceeds the maximum load drop the building structure is designed to withstand, SRS personnel must follow the unreviewed safety question process.

- While discussing this concern, SRNS personnel stated that the design process for TFF eliminated the need for critical lifts over the facility to the maximum extent practicable. SRNS personnel have also completed an initial walk-down of potential external loads and plans to analyze anticipated lifts for load values and lift paths for TFF structures. This would be a useful input for potential crane failure scenarios in the safety analysis.

- The assumed quantities of MAR released during some of the events may not be bounding [1], [2], [5]. For example, for fire and explosion events involving the failure of multiple robust containers, the MAR released is assumed to be limited to the greater of a 5 percent failure rate of the total MAR present (except for common cause events such as external impact and natural phenomena hazard), or the total loss of a single robust container. For the fire event in the vault (i.e., returned reservoir storage), the hazard evaluations assume that only a fraction of the MAR is released. These assumptions may also erroneously lead to a conclusion that the robust containers are credited to withstand a fire or explosion event. Further, the wording in other portions of the safety basis documents could lead to the same conclusion. Finally, the safety basis documents should be modified to clarify that a loss of confinement of a robust container could lead to a fire or an explosion event.

Several assumptions for the hazard evaluation and control selection do not have adequate technical bases. Such assumptions include those pertaining to the dispersion analysis, the evaluation of an aircraft crash accident, and hydrogen gas distribution in the facility:

- In the August 19, 2011, letter to NNSA, Review of Safety Basis, Tritium Facilities, Savannah River Site, the Board raised concerns regarding the safety methodology applied to the operating Tritium Facilities at SRS. Specifically, the Board stated: "The dry deposition velocity for tritium oxide (0.5 cm/s) recommended for use in the MACCS2 Computer Code Application Guidance for Documented Safety Analysis Final Report and used in the consequence analysis for the tritium facilities does not yield the bounding consequence." As a result, DOE and the contractor engaged in revising the methodology for calculating the site dose consequence, as summarized in the Dispersion Modeling Project Implementation [6]. This project recommended using a deposition velocity of 0.0 cm/sec for tritium plume dispersion analyses. SRS personnel performed MACCS2 calculations to evaluate releases for a set of stack heights using the SRS meteorological data for calendar years 2002–2006 [7]. The intent of the evaluation was to determine the reduction factor needed to decrease the unmitigated dose consequences to co-located workers from thousands of rem total effective dose to acceptable lower values. For example, the calculation showed that a stack height of about 40 meters would provide a reduction factor of about 125. The staff's review of these calculations found the following anomalies:

    - The calculations use a stack reduction factor that was derived for filtered plutonium-239 particles with a 0.01 cm/sec deposition velocity even though the Dispersion Modeling Project Implementation strategy recommended using a deposition velocity of 0.0 cm/sec for tritium [6], [7].

    - The calculation states that the computed dose reduction factor is the ratio of the dose for a ground level release to the elevated release [7]. The maximum dose that the co-located worker could be exposed to would be at the plume touchdown location, which depends on the stack height. SRNS personnel presented the results of the calculated dose as a function of the distance from the release point for several stack heights; the personnel stated that the peak dose values indicated the plume touchdown locations [8].

The staff found that the results contained some anomalies. For example, the results show that the locations of the maximum dose to the co-located worker (what SRNS personnel referred to as plume touchdown locations) for stack heights of 10, 20, and 30 meters are about 300, 900, and 100 meters, respectively, from the base of the stack. This is anomalous, because higher release points typically correspond to more distant plume touchdown locations, for a given set of weather conditions. The staff concluded that these calculations warrant further evaluation to confirm their validity.

- The analysis of an aircraft crash accident is based on a generic evaluation that uses the past crash history at the site to classify this accident as not credible. The Board identified deficiencies in SRS's evaluation in its November 6, 2019, letter to the Secretary of Energy on the need to update DOE Standard 3014, *Accident Analysis for Aircraft Crash into Hazardous Facilities*, and address safety issues related to aircraft crash analyses across DOE's defense nuclear complex.

    - As detailed in the Board's November 6, 2019, letter, the SRS analysis deviates from using the aircraft crash probabilities outlined in DOE Standard 3014, using a general aviation aircraft crash density of 5.0×10^{-5} crashes/square mile/year instead of 2.0×10^{-4} (the value in the standard). The SRS analysis justifies the reduced probability as follows: "The Savannah River Site is approximately 310 square miles. The site has existed for over 65 years... [and] there has not been an aircraft crash on SRS. This is significant given the large land area as well as the long time span. If the crash density specified in the DOE Standard were applied, SRS should have seen 3–4 aircraft crashes over this time period" [9]. The staff concluded that this rationale is flawed because it relies on the past crash history at the site as the sole justification for screening out future events. This approach is not consistent with the recommended methodology outlined in DOE Standard 3014 for producing "conservative and consistent" analyses.

    - The Board's November 6, 2019, letter also identified that the SRS evaluation ignored other site activities by crediting administrative procedures used for their operation. These include flight activities by the US Army for training purposes. DOE's accident analysis methodologies do not allow crediting any administrative controls in the unmitigated analysis.

The aircraft crash analysis used for developing the TFF design and safety basis should be revised to ensure that it is consistent with the methodology outlined in DOE Standard 3014. Alternatively, a facility-specific analysis that follows the methodology prescribed by the standard may be performed.

- The preliminary hazard analysis assumes that tritium released in a room is uniformly distributed. The analysis states: "A release of 200 g does not exceed the [lower

> flammability level] of hydrogen in a 19-m^3 space. The design must ensure that all process rooms in Building 1 exceed 19 m^3." SRNS personnel stated that this is consistent with accepted assumptions in the documented safety analysis for the operating Tritium Facilities. The staff notes that this assumption excludes consideration of local accumulations of hydrogen. The TFF CD-1 documentation should provide adequate technical bases to support this assumption or identify a design requirement to ensure that such accumulation and associated hazards are prevented or mitigated.

Identification and Classification of Controls—The CD-1 documentation identified the Building 1 structure as a safety class control to ensure adequate protection of the public and the workers. However, the safety function for the building structure does not address an explosion hazard posed by the storage of gas cylinders located adjacent to the building. A typical structural analysis does not cover this type of accident; therefore, a dedicated analysis must be performed.

The preliminary hazard analysis and the CSDR contain the following discussions: "The hazard analysis concluded that the following events resulted in high consequences to the [facility worker] as a result of natural phenomena hazard events while containers were being transported from Building 233-H to Building 1 through the corridor in Building 249-H… The control initially selected to prevent the event was to design the corridor to NDC-3 criteria. This corridor is in an existing building that was not initially designed to NDC-3. As the design matures, it may be determined that the foundation, soils, or other features of this building cannot be upgraded to NDC-3, in which case, the following options will be considered." It recommends to "justify acceptance of a higher risk to the [co-located worker] for the Building 249-H portion of this scope. The basis for the risk acceptance is that it exists now for transportation to/from H-Area Old Manufacturing (with the only mitigator as the emergency response program)…" SRNS personnel stated that that the final decision regarding the design requirements for the Building 249-H corridor has not been made and the final recommendation will be made during the upcoming design activities. The staff notes it would be appropriate to identify engineered design features to prevent these consequences instead of accepting high consequences to the workers. As stated previously, NNSA has decided to descope the 249-H renovations from the TFF project and build a new corridor.

The preliminary fire hazard analysis states that Building 1 will be equipped with a safety class wet sprinkler system throughout and supplied by two redundant water supplies to prevent small facility fires from propagating. The analysis proposed that only one of the water supplies be safety class, the other one being the existing general service H-Area water loop. The analysis justified this recommendation based on a recent change in DOE Standard 1066, *Fire Protection*, i.e., exclusion of the "safety class" designation in the requirement to have two water supplies. The staff notes the analysis is misinterpreting an editorial change in the standard. Relying on a single safety class water supply may require placing the facility into a standby condition during water supply maintenance activities.

Code of Record—Following the CD-1 approval, the project issued a revised facility design description, which contained an updated code of record [10] incorporating codes and standards omitted from the CD-1 documentation. However, the preceding code of record, which lacks this information, was still an active project document. In addition, the newly applied codes and standards have not been incorporated into all design documentation, e.g., the system design descriptions. For example, the system design description for the ventilation system does not include the American Society of Mechanical Engineers (ASME) AG-1, *Code for Nuclear Air and Gas Treatment* [11], which DOE Order 420.1C identifies as the relevant code for the design of safety significant fans and ductwork that a facility would rely on for protection of the facility and co-located worker. In addition, the preceding code of record did not include all relevant standards outlined in DOE Order 420.1C for the electrical systems credited in the CSDR as safety-related [2].

Software Quality Assurance—The project personnel used MACCS2 v1.13.1 to calculate the dose consequences to receptor groups for both elevated and ground-level releases in accident scenarios for control selection. The project personnel also used GENII v2.10.1 to determine site-specific deposition velocities and the 95th percentile air concentrations using the five-year data sets of site meteorological data as input for the MACCS2 v1.13.1 dose calculations. The safety design strategy outlines the strategy for performing dispersion modeling analysis using an updated MACCS code as directed by DOE [1]. It references the dispersion modeling project implementation plan for using MACCS2 v1.13.1, which provides the modeling details for MACCS2 and GENII, but does not resolve the plume dispersion and dose consequence analysis concerns associated with this version [6].

Both MACCS2 v1.13.1 and GENII v2.10.1 are the versions DOE approved in its safety software quality assurance (SSQA) central registry of toolbox codes. GENII v2.10.1 was approved in 2013 and is still the latest version. MACCS2 v.1.13.1 is outdated and no longer supported by its developer; MACCS v4.0 and WinMACCS v4.0 are the current versions. MACCS2 v1.13.1 was approved in 2004 for the Windows operating system but was not developed for use on Windows 7 and 10 platforms utilized by the project personnel. SRNS personnel informed the staff that they have tested MACCS2 v1.13.1 on Windows 7 and 10 platforms. The staff notes that the TFF project should consider using the latest MACCS version to address the plume dispersion and dose consequence concerns associated with the outdated version. Alternatively, the TFF project could perform a gap analysis to address these concerns.

In 2004, DOE published the gap analysis and code usage guidance for both MACCS2 v1.13.1 and earlier GENII versions. At the time, the quality assurance improvement measures to meet SSQA standards were still pending. Prior to inclusion into the central registry, an evaluation or gap analysis of each code is performed to identify any "gaps" between the SSQA practices being followed and DOE's requirements and criteria for safety software. Code-specific guidance reports identify applicable regimes in accident analysis, default inputs, and special conditions for using the toolbox codes for DOE applications. The gap analyses for these codes were completed before issuance of DOE Order 414.1C, *Quality Assurance*, and DOE Guide 414.1-4, *Safety Software Guide for Use with 10 CFR 830 Subpart A, Quality Assurance Requirements*, which provide a framework for the evolving DOE requirements for safety software. DOE defined its safety software requirements more clearly with the release of DOE Order 414.1C and Guide 414.1-4, and subsequently DOE Order 414.1D. In August 2013, DOE completed an evaluation of the latest GENII v2.10.1 against DOE's SSQA criteria and listed this version in the central registry.

To meet SSQA standards, even for DOE toolbox codes, users must follow the DOE toolbox code guidelines and perform the gap analyses to address restrictions and limitations of the code, e.g., known limitations in the atmospheric model of MACCS2 v.1.13.1 [12]. DOE Handbook 1224, *Hazard and Accident Analysis Handbook*, provides additional guidance and discusses limitations of MACCS2 and GENII. The handbook states that every toolbox model needs to be independently evaluated according to the SSQA principles in DOE Order 414.1D and additional guidance in DOE Guide 414.1-4. DOE is working with the code developers/owners to have the toolbox codes updated (e.g., closing the gaps) and maintained following SSQA provisions of applicable national consensus standards. For example, American National Standards Institute/ASME NQA-1-2008, *Quality Assurance Requirements for Nuclear Facility Applications*, is the preferred standard cited in DOE Order 414.1D for safety software. As prefaced in the DOE SSQA central registry, DOE is responsible for managing the registry; however, the toolbox code owners are responsible for ensuring that the codes are maintained in accordance with established DOE SSQA requirements and guidance.

Tracking Open Items—As previously noted, Parsons prepared and submitted the CD-1 documentation for DOE approval in 2018, whereas SRNS will complete the facility design. Parsons made numerous assumptions and established initial conditions while preparing the conceptual design, safety basis, and supporting documents. These assumptions and initial conditions have not been consolidated in a single tracking system. In addition, the TFF project does not seem to have a systematic tracking process to ensure that all assumptions and initial conditions are revisited in the subsequent phases of design for proper application and closure of open items.

DOE Guide 413.3-1 Chg 1, *Managing Design and Construction Using Systems Engineering for Use with DOE O 413.3A*, indicates that the process of collecting and/or generating missing information and incomplete knowledge, including unverified assumptions, is a project in itself. The guide recommends developing a formal database that identifies each uncertainty. DOE Standard 1189, *Integration of Safety into the Design Process*, indicates that safety analysis assumptions should be evaluated in the project risk and opportunity assessment as potential risks and serve as input into the risk management plan. It is of utmost importance for the project personnel to revisit the CD-1 documentation to identify embedded assumptions and initial conditions and ensure proper and adequate closure of open items as the facility design matures.

Conclusion. The staff reviewed the safety basis and design documents associated with the CD-1 milestone and identified observations in several key areas: confinement strategy, hazard and accident analysis, identification and classification of controls, code of record, software quality assurance, and the tracking of open issues. NNSA will need to address the observations as the design matures to ensure TFF meets DOE's safety requirements. The staff plans to reengage with project personnel when the facility design reaches 30 percent completion to follow up on identified observations and to review the project design and safety basis to ensure adequate protection of the health and safety of workers and the public.

References

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[11] Parsons, *Tritium Production Capability Project System Design Description Ventilation Exhaust System,* ECMS-TPC-PSDD-0005 Rev 0, October 2017.

[12] Savannah River Nuclear Solutions, *PNNL-20990: Final Review of Safety Assessment Issues at Savannah River Site,* S-ESR-G-00015 Rev 0, August 2011.