Safety Basis Assessment at the Savannah River Site Tritium Facility

May 2020

Office of Enterprise Assessments
U.S. Department of Energy

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Acronyms

BDBA	Beyond Design Basis Accident
CFR	Code of Federal Regulations
CHA	Consolidated Hazard Analysis
CW	Collocated Worker
DBA	Design Basis Accident
DiD	Defense in Depth
DOE	U.S. Department of Energy
DSA	Documented Safety Analysis
EA	Office of Enterprise Assessments
EG	Evaluation Guideline
FSS	Fire Suppression System
FW	Facility Worker
LCO	Limiting Condition for Operation
MAR	Material at Risk
MOI	Maximally Exposed Offsite Individual
NNSA	National Nuclear Security Administration
OE-1	Operating Experience Level 1
OFI	Opportunity for Improvement
SAC	Specific Administrative Control
SBRT	Safety Basis Review Team
SC	Safety Class
SER	Safety Evaluation Report
SMP	Safety Management Program
SRFO	Savannah River Field Office
SRNS	Savannah River Nuclear Solutions, LLC
SRS	Savannah River Site
SS	Safety Significant
SSCs	Structures, Systems, and Components
TSR	Technical Safety Requirements Document
TSRs	Technical Safety Requirements

Safety Basis Assessment at the Savannah River Site Tritium Facility December 2018 through November 2019

Summary

Scope:
This assessment evaluated the development and approval of the upgraded documented safety analysis (DSA) and technical safety requirements document (TSR) at the Savannah River Site (SRS) Tritium Facility.

Significant Results for Key Areas of Interest:
The revised DSA and TSR for the SRS Tritium Facility comply with DOE-STD-3009-94, *Preparation Guide for U.S. Department of Energy Nonreactor Nuclear Facility Documented Safety Analyses*, and the safety evaluation report (SER) complies with DOE-STD-1104-2016, *Review and Approval of Nuclear Facility Safety Basis and Safety Design Basis Documents.*

Documented Safety Analysis
The DSA generally conforms to the requirements of DOE-STD-3009-94 and adequately supports the safe operation of the Tritium Facility.

- Hazard identification is comprehensive and systematic.
- The hazard evaluation and accident analysis provide appropriately detailed representative events with conservative consequences and compliant bases for control selection and functional classification of safety structures, systems, and components (SSCs). However, the assessment team identified concerns in that multiple hazard events have high mitigated consequences to the collocated worker (CW).
- The safety SSCs' safety functions, functional requirements, and performance criteria are clearly described, and the system evaluations support a sufficient understanding of how the safety functions are satisfied.
- The DSA adequately describes key attributes of the specific administrative controls (SACs) required to support the safety functions identified in the hazard and accident analyses.

Although the DSA is not required by contract to incorporate the updated requirements in DOE-STD-3009-2014, *Preparation of Nonreactor Nuclear Facility Documented Safety Analysis*, applying the standard's provisions to evaluate the effectiveness of controls and to provide a technical basis for accepting the CW residual risks is identified as an opportunity for improvement.

Technical Safety Requirements and Their Derivation
The TSR sufficiently ensures that SSCs and SACs meet their safety functions and functional requirements.

- The technical safety requirements appropriately reflect the identified control safety functions, functional requirements, and performance criteria developed in the DSA.
- Limiting conditions for operation, surveillance requirements, and associated bases are consistent with the control development and evaluation in the DSA.
- SACs and design features are adequately described.

Federal Oversight
The SER addresses the DOE-STD-1104-2016 approval bases and concludes that the DSA/TSR provide reasonable assurance of adequate protection of workers, the public, and the environment from adverse consequences.

Best Practices and Findings
No best practices or findings were identified during this assessment.

Follow-up Actions:
No follow-up activities are planned.

Safety Basis Assessment at the Savannah River Site
Tritium Facility

1.0 INTRODUCTION

The U.S. Department of Energy (DOE) Office of Nuclear Safety and Environmental Assessments, within the independent Office of Enterprise Assessments (EA), conducted an assessment of the upgraded documented safety analysis (DSA), technical safety requirements document (TSR), and safety evaluation report (SER) for the Savannah River Site (SRS) Tritium Facility. This assessment, conducted from December 2018 through November 2019, is part of ongoing targeted assessments of safety basis documents at SRS.

In accordance with the *Plan for the Independent Oversight Targeted Review of Documented Safety Analysis Upgrades at the Savannah River Site, December 2014,* this assessment covered the development and approval of the upgraded Tritium Facility safety basis, which includes the DSA and TSR. When the review was initiated, the Tritium Extraction Facility and Tritium Facility had separate safety basis documents, which were subsequently combined. Consistent with the review plan, information relevant to the Tritium Extraction Facility safety basis in the combined document was excluded from this assessment. This assessment encompassed review of the hazard and accident analyses, including hazard controls and beyond design basis accidents (BDBAs); safety structures, systems, and components (SSCs) and specific administrative controls (SACs); and derivation of technical safety requirements (TSRs). The DSA accident analysis incorporates the revised atmospheric radiological dispersion analysis methodology based on SRS plan S-ESR-G-00033, *Dispersion Modeling Project Implementation*. The assessment team evaluated implementation of the requirements of DOE Operating Experience Level 1 (OE-1) document 2013-01, *Improving Department of Energy Capabilities for Mitigating Beyond Design Basis Events*. The assessment also included review of the SER, which documents the review and approval of the DSA and TSR by the National Nuclear Security Administration (NNSA) Savannah River Field Office (SRFO).

The Tritium Facility includes process buildings in H-Area at SRS. Building 233-H provides reservoir/special container processing, isotope separation/purification, byproduct (helium-3) purification, and environmental conditioning. Building 234-H provides tritium reservoir preloading, packaging, and shipping, as well as inert reservoir loading, finishing, packaging, and shipping. Vault 217-H provides tritium container storage and is considered part of Building 234-H. Building 234-7H supports reservoir surveillance and gas transfer operations. Building 233-1H is an enclosed passageway that connects Buildings 233-H, 234-H, and 234-7H, as well as 249-H, which is a service building that houses auxiliary equipment.

Savannah River Nuclear Solutions, LLC (SRNS) manages and operates the Tritium Facility under the direction and oversight of SRFO. The Tritium Facility's current mission is to support national defense programs involving nuclear weapons by providing DOE and the Department of Defense with reservoirs filled with deuterium/tritium mixtures that meet Weapons Design Agency requirements. It also supplies tritium to both agencies on a smaller scale for research and development uses.

2.0 METHODOLOGY

The DOE independent oversight program is described in and governed by DOE Order 227.1A, *Independent Oversight Program*, which is implemented through a comprehensive set of internal protocols, operating practices, assessment guides, and process guides. This report uses the terms "best practices, deficiencies, findings, and opportunities for improvement (OFIs)" as defined in the order.

As identified in the assessment plan, this assessment considered requirements for the Tritium Facility safety basis documents from 10 CFR Part 830, "Nuclear Safety Management"; DOE-STD-3009-94, *Preparation Guide for U.S. Department of Energy Nonreactor Nuclear Facility Documented Safety Analyses*; and DOE-STD-1104-2016, *Review and Approval of Nuclear Facility Safety Basis and Safety Design Basis Documents*. Key aspects of these requirements are included in the objectives and criteria of EA Criteria and Review Approach Document 31-3 (Rev. 0), *Safety Basis Upgrade Review Criteria Review and Approach Document*.

The assessment team examined key documents, such as the consolidated hazard analysis (CHA), fire hazards analyses, safety basis strategy, system design descriptions, accident analyses, design calculations, and engineering drawings. The assessment team also conducted meetings with key SRNS personnel and SRFO Safety Basis Review Team (SBRT) members responsible for developing and reviewing safety basis documents. Appendix A lists the members of the assessment team, the Quality Review Board, and EA management responsible for this assessment.

There were no items for follow-up during this assessment.

3.0 RESULTS

3.1 Documented Safety Analysis

3.1.1 Hazard and Accident Analyses (Chapter 3)

The objective of the assessment of Chapter 3 of the DSA and the CHA was to evaluate hazard identification and evaluation, including the designation of hazard controls. The review included events related to fires, explosions, loss of confinement, and natural phenomena hazards and man-made external events for Buildings 233-H, 233-1H, 234-H, and 234-7H and Vault 217-H. No chemical exposure hazard events exceed the limits for the collocated worker (CW); therefore, none of these hazard events are carried into the DSA. Criticality events are not credible because there is no fissile material in any of these buildings. No radiological hazard events exceed the Evaluation Guideline (EG) of 25 rem to the public. The Tritium Facility hazard categorization of hazard category 2 is appropriate per DOE-STD-1027-92, *Hazard Categorization and Accident Analysis Techniques for Compliance with DOE Order 5480.23, Nuclear Safety Analysis Reports*.

3.1.1.1 Hazard Identification

SRNS prepared a separate hazard analysis document (S-CHA-H-00030, *Consolidated Hazard Analysis for the Savannah River Site Tritium Facilities*) to support the DSA. The hazard identification process used the hazard analysis in the current safety basis and added any new hazards identified through facility walkdowns performed as part of CHA development. The CHA contains hazards identification tables for each building, and a summary table is presented in the DSA. The CHA hazards identification is comprehensive, and hazards for all processes are systematically documented. Tritium material at risk (MAR) is conservatively based on bounding values for both facility-wide and process-related events and is established as an initial condition for the hazard evaluation. The MAR is appropriately described in terms of quantity, form, and location. Worker safety hazards are included in the DSA, and in some cases, worker actions are considered as initiating events. Overall, the DSA adequately identifies and categorizes the hazards associated with Tritium Facility operations.

3.1.1.2 Hazard Evaluation

The CHA briefly describes the facilities and operational processes, and it documents the results of the hazard evaluation. The CHA includes the inputs and assumptions developed during the hazard analysis process to establish a technical baseline. The CHA development team primarily used the "What-If" technique to identify hazard events. The Tritium Facility was divided into specific locations or process activities to facilitate the identification and evaluation of hazardous events. The hazard evaluation analyzes normal operational and maintenance processes, as well as abnormal and accident conditions. The evaluation includes natural phenomena hazards events (e.g., seismic, lightning, and tornado) and man-made external events (e.g., aircraft crash, external fires, and vehicle impacts).

The CHA uses risk bins based on qualitative estimates for initiating event frequencies and quantitative radiological dose consequences to the public and CW. Likelihood estimates are consistent with the frequency bins identified in DOE-STD-3009-94, and initiating event frequencies are conservative. Hazard event consequences are evaluated against the EG and the radiological consequence threshold of 100 rem to the CW. Consequences are conservatively estimated, and safety controls are appropriately classified. However, the assessment team identified concerns with hazard events having high mitigated consequences to the CW.

Multiple hazard events result in high mitigated consequences to the CW, including building-wide fires, impacts, explosions, and seismic events, all with the potential to release large quantities of tritium. Most of these CW consequences are over 1000 rem, with bounding events resulting in approximately 9,500 rem. When a control has been identified, the DSA does not demonstrate the adequacy of the control and does not provide technical justification for acceptance of the high CW consequences. In several events with high mitigated consequences, some potentially viable safety controls are not credited. For example, the seismic tritium confinement system is identified as an available control, but it is not credited as safety significant (SS) for several seismic events.

The DSA follows DOE-STD-3009-94, which does not explicitly require demonstration of control adequacy. While not a contractual requirement for the Tritium Facility, the more recently promulgated DOE-STD-3009-2014, *Preparation of Nonreactor Nuclear Facility Documented Safety Analysis*, incorporates 20 years of experience and lessons learned from using DOE-STD-3009-94 and provides clearer requirements for developing DSAs. DOE-STD-3009-2014 requires a mitigated consequence analysis to demonstrate the effectiveness of the controls to reduce CW consequences below 100 rem. Where there are no viable controls to achieve 100 rem, the updated standard requires the DSA to provide a technical basis for acceptance of the mitigated consequences, including the basis for not crediting other available controls. Applying these DOE-STD-3009-2014 provisions for events with high CW residual risk would provide an evaluation of the effectiveness of controls (§ 3.2.3) and a technical basis for accepting the residual risk (§ 3.3.2). (See **OFI-SRFO-1**.)

DSA § 3.3.2.3.1 identifies four planned design and operational safety improvements that include the development of a technical basis for elemental tritium conversion to oxide resulting from fires and explosions. The hazard evaluation conservatively assumes a 100% elemental conversion to oxide for all tritium releases involving fire or explosions, which may represent a significant overestimation of the potential dose consequences and associated risks. In addition, SRNS has issued a strategy (U-ESR-H-00163, *Strategy for Risk Reduction to the Co-located Worker*, Rev. 0) to document a multi-year path forward for reducing consequences to the CW; this strategy has been accepted by SRFO. Although this strategy should result in reduced consequences to the CW, it does not address DSA demonstration of control adequacy. (See **OFI-SRFO-1**.)

The hazard analysis addresses an appropriate range of hazardous materials and energy sources and includes a thorough set of hazard events. The CHA hazard evaluation tables include the estimated risk bins for both unmitigated and mitigated hazard events. The tables identify controls that provide preventive or mitigative safety functions in specific hazard events, except as identified above. The DSA provides a summary of the design basis accidents (DBAs) and their unmitigated and mitigated frequencies and consequences. The hazard analysis appropriately identifies safety SSCs and SACs based on the risk, except as identified above.

The assessment team reviewed the accident analysis in Chapter 3 of the DSA and supporting calculations to determine whether it is sufficiently conservative to derive an adequate set of safety controls. The DBAs are based on representative and unique scenarios that include facility fire, external events resulting in fire, and natural phenomena hazards events resulting in fire or loss of confinement. For each DBA scenario, the analyses provide suitably detailed discussions of scenario development, the MAR, radiological consequences, a comparison to dose thresholds, and a summary of credited and defense-in-depth (DiD) controls. The accident analysis is sound, addressing an appropriate set of representative and unique accident scenarios as derived from the hazard evaluation. The accident analysis includes a quantitative consequence calculation for both unmitigated and mitigated scenarios. The consequence methodology is conservative and adequately assesses dose consequences (e.g., releases are assumed to be 100% tritium oxide for fires and explosions; leak path factors are assumed to be 1.0; airborne release fractions and respirable fractions are assumed to be 1.0 for release of tritium gas).

3.1.1.3 Hazard Controls

The assessment team reviewed hazard events identified in Chapter 3 of the DSA to verify that safety controls are appropriately classified. Although radiological consequences to the maximally exposed offsite individual (MOI) do not exceed the EG, safety class (SC) controls are conservatively applied to reduce consequences to the MOI. Fire barriers that are credited for preventing propagation of fires between buildings, as well as the Vault 217-H structure, are classified as SC. Further, the Inventory Controls SAC is designated as SC to ensure that public consequences are below the EG.

Chapter 3 of the DSA identifies controls for the protection of workers from the hazards of process operation, exclusive of standard industrial hazards. With the exception of the events noted above, SS SSCs and SACs are identified to prevent or mitigate accidents exceeding 100 rem to the CW and to protect the facility worker. The DSA Chapter 3 and CHA discussions of the control strategy for the fire and explosion events provide a reasonable basis for the choice of hazard controls. The SS secondary confinement systems, together with the SS glovebox oxygen monitoring systems and the DiD exhaust ventilation system, provide adequate preventive controls for fires and explosions with the potential for adverse consequences to workers. Likewise, the SS Environmental Conditioning enclosure oxygen monitoring systems work in conjunction with the SS Environmental Conditioning enclosures to prevent explosions. The safety functions and functional requirements for these SSCs are adequate to meet the hazard control requirements derived in the safety analysis.

Safety controls are properly identified and include the safety function, control type, and listing of applicable hazard events. The selection of hazard controls follows the control hierarchy recommended by DOE-STD-3009-94, and the controls are adequate to prevent or mitigate the analyzed accidents except as noted above.

3.1.1.4 Defense in Depth

The DSA effectively incorporates the DiD principles described in DOE-STD-3009-94. SSCs and administrative controls provide preventive or mitigative functions so that multiple barriers are available for the protection of workers and the public for postulated events; the barriers include independent credited and non-credited controls. The Fire Protection safety management program (SMP) provides detection and notification, response processes, procedures, and training for workers, and it also describes key elements of the program.

3.1.1.5 Beyond Design Basis Accidents

The DSA identifies two BDBAs that could result in a full facility fire. Both BDBAs are evaluated to provide a consequence of 23 rem to the MOI using the bounding facility MAR. Attachment 2 of OE-1 2013-01 provides the expectation that all potential causes for a BDBA will be evaluated; however, with a maximum BDBA dose consequence less than the EG, the OE-1 2013-01 requirements do not apply. Due to the consequence values, no additional controls are identified.

3.1.2 Safety SSCs and SACs (Chapter 4)

The objective of the assessment of Chapter 4 of the DSA was to verify that the functional classification of safety controls is appropriate and to assess whether the safety functions, functional requirements, and performance criteria are adequate. Chapter 4 adequately identifies the safety functions for credited safety controls and provides the criteria to ensure that the controls can perform their safety functions and to support subsequent derivation of the TSRs.

As discussed in Section 3.1.1.3, the DSA identifies fire barriers and the Vault 217-H structure as SC controls to protect the public. Multiple passive design features (e.g., robust containers, Vault 217-H highly invulnerable encased safes, transfer line jackets, secondary confinement systems) and multiple active SSCs (e.g., fire suppression systems [FSSs], oxygen monitoring systems, tritium air monitors, interlocks, check valves) are identified as SS for the protection of workers. The safety functions are consistent with those identified in the hazard and accident analyses. The functional requirements adequately address the nuclear safety hazards, and the system evaluations adequately assess control performance.

Chapter 4 of the DSA identifies two SC SACs and ten SS SACs for the protection of the public and workers, respectively. Examples of SACs include inventory controls, combustible material controls, empty container verification controls, and the explosion prevention program. For each SAC, the DSA provides its safety function, description, and functional requirements. The safety functions are consistent with those identified in the hazard and accident analyses. The DSA also includes an evaluation section that assesses the ability of each SAC to meet its safety functions. The functional requirements and SAC evaluations sufficiently describe how the SACs meet their safety functions.

3.1.3 Documented Safety Analysis Conclusion

In summary, the DSA meets the requirements of DOE-STD-3009-94 and comprehensively identifies and evaluates the hazards associated with the Tritium Facility and its processes. The hazard analysis appropriately addresses hazardous materials and energy sources and postulates an adequate set of hazard events. Excluding concerns about hazard events resulting in high mitigated CW consequences, the control strategies are adequate to reasonably ensure the safety of workers and the public. The safety functions and functional requirements in Chapter 4 of the DSA for SSCs and SACs are sufficiently defined to meet the hazard control requirements derived in the hazard analysis. The evaluations of the SSCs and SACs are sufficient to ensure that safety functions can be met.

3.2 Technical Safety Requirements and Their Derivation (Chapter 5)

The objective of the assessment of Chapter 5 of the DSA and the TSR was to evaluate selected TSRs, their bases, and associated derivation to verify accurate translation of credited SSCs and performance requirements into a set of formal and implementable requirements. These requirements preserve the identified safety functions, functional requirements, and performance criteria developed in Chapters 3 and 4 of the DSA. The Tritium Facility TSRs and their derivation generally meet the requirements of DOE-STD-3009-94, and the format and content conform to DOE Guide 423.1-1B, *Implementation Guide for Use in Developing Technical Safety Requirements*. Modes and mode restrictions for process areas are clearly defined in Chapter 5 of the DSA and carried forward into the TSR. Limiting conditions for operation (LCOs) are consistent with the control development in the DSA. The LCO bases appropriately include information from the DSA used in derivation of the controls. Design features are adequately described, with appropriate in-service inspection and configuration management requirements. SACs are adequately described, and administrative controls appropriately include commitments to the SMPs. Surveillance requirements are consistent with the DOE guide and have justifiable frequencies.

The fire hazards and controls are adequately documented in the DSA, which also references the supporting fire hazards analysis and fire scenario development documents. The FSS includes a non-safety support system outside of Tritium Facility control where surveillances necessary to ensure operability are required by a TSR administrative control (Section 5.7.2.3). Responsibility for the non-safety portions of the FSS belongs to SRS Infrastructure Services. Although a 2009 Office of Health, Safety and Security inspection of the Tritium Extraction Facility raised concerns about this division of responsibility, this assessment found that the memorandum of understanding between Tritium Facility management and Infrastructure Services adequately defines the responsibilities for ensuring operability of the FSS SSCs.

3.3 Federal Review and Approval

EA reviewed the SER to determine its adequacy as the approval basis for the DSA, as required by DOE-STD-1104-2014.

The SBRT completed the DSA and TSR review and developed the SER in accordance with the approved review plan. NNSA procedure SV-PRO-030, *SRFO Nuclear Safety Oversight*, Section 2, SER Content Guidance, addresses safety basis document reviews (including review and approval of the DSA and TSR) and provides guidance on the review approach, risk acceptance, format, and content of SERs.

The SRFO SBRT included a team leader, Facility Representatives, a safety system oversight engineer, nuclear safety specialists, a senior advisor, and a seismic structural subject matter expert. The SBRT concluded that the safety basis has been developed in a manner that provides reasonable assurance of adequate protection of workers, the public, and the environment from adverse consequences. Based on its review, the SBRT recommended approval of the upgraded DSA/TSR. The approval letter, as issued by the safety basis approval authority (the SRFO Senior Technical Safety Advisor at the time of signature), establishes the SER as the basis for approval. No conditions of approval were specified.

The SER adequately addresses the approval bases identified in DOE-STD-1104-2016, including base information, hazard and accident analyses, DiD, SSCs, SACs, derivation of TSRs, and SMPs. For each approval basis, the SER provides adequate justification to recommend approval of the DSA. SRFO recognized that for some events the mitigated consequences continued to be high for the CW and the facility worker (FW) (see **OFI-SRFO-1**). SRFO directed development of a CW risk reduction strategy that focuses on SSCs that could be modified or installed to provide additional protection to the CW and FW for hazard events.

The SER documents a compliant review and concludes that the DSA/TSR provide reasonable assurance of adequate protection of workers, the public, and the environment from adverse consequences. SRFO concludes that the risk associated with operating the Tritium Facility is acceptable and warranted given its defined national security missions and the conservative consequence analysis. The consequence analysis used bounding MAR quantities and forms, with conservative release durations and conservative source term determination assumptions.

4.0 BEST PRACTICES

There were no best practices identified as part of this assessment.

5.0 FINDINGS

There were no findings identified as part of this assessment.

6.0 DEFICIENCIES

There were no deficiencies identified as part of this assessment.

7.0 OPPORTUNITIES FOR IMPROVEMENT

The assessment team identified an OFI to assist cognizant managers in improving programs and operations. While OFIs may identify potential solutions to findings and deficiencies identified in assessment reports, they may also address other conditions observed during the assessment process. This OFI is offered only as a recommendation for line management consideration; it does not require formal resolution by management through a corrective action process and is not intended to be prescriptive or mandatory. Rather, it is a suggestion that may assist site management in implementing best practices or provide potential solutions to issues identified during the assessment.

NNSA Savannah River Field Office

OFI-SRFO-1: Due to the high level of CW residual risk associated with multiple hazard events, consider applying DOE-STD-3009-2014 to evaluate the effectiveness of controls (§ 3.2.3) and provide a technical basis for accepting the residual risk (§ 3.3.2).

Appendix A
Supplemental Information

Dates of Assessment

Document Review: December 2018 – April 2019 and November 2019
Comment Review and Responses/Discussion: February 2019

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