Independent Assessment of the Preliminary Documented Safety Analysis for the Nevada National Security Site U1a Enhanced Capabilities for Subcritical Experiments Project

September 2022

Office of Enterprise Assessments
U.S. Department of Energy

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Acronyms

BEU	Beyond Extremely Unlikely
COA	Condition of Approval
CW	Co-located Worker
DBA	Design Basis Accident
DOE	U.S. Department of Energy
EA	Office of Enterprise Assessments
ECSE	Enhanced Capabilities for Subcritical Experiments
EG	Evaluation Guideline
FMC	Fissile Material Container
FW	Facility Worker
LCO	Limiting Condition for Operation
MAR	Material at Risk
MOI	Maximally Exposed Offsite Individual
MSTS	Mission Support and Test Services, LLC
NFO	Nevada Field Office
NNSA	National Nuclear Security Administration
PDSA	Preliminary Documented Safety Analysis
SAC	Specific Administrative Control
SBRT	Safety Basis Review Team
SCE	Subcritical Experiment
SER	Safety Evaluation Report
SSCs	Structures, Systems, and Components
TSRs	Technical Safety Requirements

INDEPENDENT ASSESSMENT OF THE PRELIMINARY DOCUMENTED SAFETY ANALYSIS FOR THE NEVADA NATIONAL SECURITY SITE U1A ENHANCED CAPABILITIES FOR SUBCRITICAL EXPERIMENTS PROJECT

Executive Summary

The U.S. Department of Energy (DOE) Office of Enterprise Assessments (EA) conducted an independent assessment of the preliminary documented safety analysis (PDSA) and safety evaluation report (SER) for the U1a Complex Enhanced Capabilities for Subcritical Experiments (ECSE) Project at the Nevada National Security Site from October 2021 to May 2022. This assessment considered requirements for the ECSE Project safety design basis documents from DOE-STD-1189-2016, *Integration of Safety into the Design Process*, and DOE-STD-1104-2016, *Review and Approval of Nuclear Facility Safety Basis and Safety Design Basis Documents*.

EA identified the following strengths:

- The ECSE hazards are clearly identified and characterized.
- The accident analysis evaluates an appropriate set of representative and unique design basis accidents derived from the hazard evaluation.
- The selection of hazard controls follows the DOE-STD-1189-2016 preferred control hierarchy.
- The control evaluations provide assurance that safety functions can be met.
- The SER meets the requirements of DOE-STD-1104-2016 and adequately documents the basis for approving the PDSA.

EA identified two deficiencies as summarized below:

- The PDSA does not meet the conditions specified in DOE-STD-3009-2014, *Preparation of Nonreactor Nuclear Facility Documented Safety Analysis*, for using an alternate dispersion factor based on a co-located worker receptor distance more than 100 meters from the point of release.
- Contrary to the requirements of DOE-STD-3009-2014 for the design of hazard controls, the analysis of the postulated vehicle fire at the collar area is insufficient for deriving the performance criteria for the Fissile Material Container.

In summary, except for the deficiencies noted above, the PDSA and SER for the U1a Complex ECSE Project at the Nevada National Security Site meet the respective requirements of DOE-STD-1189-2016 and DOE-STD-1104-2016.

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1.0 INTRODUCTION

The U.S. Department of Energy (DOE) Office of Nuclear Engineering and Safety Basis Assessments, within the independent Office of Enterprise Assessments (EA), conducted an assessment of the preliminary documented safety analysis (PDSA) and safety evaluation report (SER) for the U1a Enhanced Capabilities for Subcritical Experiments (ECSE) Project at the Nevada National Security Site. This assessment, which began in October 2021 and concluded in May 2022, is part of an ongoing effort to conduct independent oversight of high-hazard nuclear facility construction projects in support of legislative direction.

This assessment was conducted in accordance with the *Plan for the Independent Assessment of the Nevada National Security Site U1a Complex Enhanced Capabilities for Subcritical Experiments Project Preliminary Documented Safety Analysis*. The scope of this assessment encompassed review of the hazard and accident analyses, safety significant controls, and preliminary derivation of technical safety requirements (TSRs). The scope also included review of the SER that documents the basis for National Nuclear Security Administration (NNSA) approval of the PDSA.

Mission Support and Test Services, LLC (MSTS) manages the Nevada National Security Site under the direction and oversight of the NNSA Nevada Field Office (NFO). The U1a Complex provides an underground experiment test bed for subcritical experiments (SCEs) conducted by the NNSA nuclear weapons laboratories. The U1a Complex is an operating facility that will be enlarged by the ECSE Project. The ECSE Project adds a new zero room for SCEs and an accelerator. These improvements constitute a major modification to the U1a Complex.

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, and other documented guidance. This report uses the terms “best practices, deficiencies, findings, and opportunities for improvement” as defined in the order.

This assessment considered requirements for the ECSE Project safety design basis documents from DOE-STD-1189-2016, *Integration of Safety into the Design Process*; DOE Order 420.1C, *Facility Safety*; DOE-STD-1104-2016, *Review and Approval of Nuclear Facility Safety Basis and Safety Design Basis Documents*; and other supporting DOE standards. EA used the relevant sections from Criteria and Review Approach Document EA-31-29, Rev. 1, *Review of Nuclear Facility Safety Design Basis Development*, to guide the PDSA and SER review. Focusing on selected aspects of nuclear safety that are essential for ensuring adequate protection of workers and the public, EA examined key supporting documents, including the *U1a Complex Hazard Analysis*, the preliminary fire hazards analysis, and supporting calculations. The members of the assessment team, the Quality Review Board, and EA management responsible for this assessment are identified in appendix A.

No items from previous assessments required follow-up during this assessment.

3.0 RESULTS

3.1 Preliminary Documented Safety Analysis

3.1.1 Site Characteristics

EA reviewed the general information and site characteristics in the PDSA to verify that the information is sufficient for supporting the hazard and accident analyses, control selection, and the derivation of TSRs. The PDSA and associated references include information that adequately describes the environment, natural phenomena hazards accident initiators, external event initiators, and nearby facilities.

3.1.2 Facility and Process Descriptions

EA reviewed the facility and process descriptions provided in the PDSA to verify that the information adequately supports the hazard analysis for the ECSE Project. SCE operations include configuring the test bed, inserting an experiment into a zero room, "button-up" of an experiment into a vessel confinement system, securing the zero room, executing the experiment, re-entering the zero room, and entombing previous experiments in vessel confinement systems. High explosives are used in some experiments to apply high pressures to fissile materials for research and development purposes. Process descriptions include adequate detail on confinement systems, safety support systems (e.g., shielding, weather monitoring, hoist systems), and other auxiliary systems. The PDSA provides sufficient system and equipment information for understanding the hazards associated with ECSE operations and supporting the safety analysis in the PDSA.

3.1.3 Hazard and Accident Analyses

EA reviewed the hazard and accident analyses to verify that the analyses followed the methodology described in DOE-STD-3009-2014, *Preparation of Nonreactor Nuclear Facility Documented Safety Analysis*.

Hazard Identification

The hazard identification methodology in the PDSA is based on the approach described in DOE-STD-3009-2014. The preliminary hazard analysis identifies potential hazards and subsequent abnormal and accident events. The material at risk (MAR) is appropriately described in terms of quantity and form (i.e., radioactive material with or without high explosive). Energy sources are appropriately identified. Worker safety hazards are included, and in some cases, operator error is considered as an initiating event. The ECSE hazards are adequately identified and characterized.

Hazard Evaluation

EA reviewed the hazard events identified in the PDSA, namely fires, explosions, loss of confinement, direct radiation exposure, natural phenomena, and man-made external events. Nuclear criticality safety evaluations conclude that inadvertent criticality events are not credible. The hazard evaluation appropriately includes hazard screening, unmitigated and mitigated consequence and frequency estimations, and hazard control selection for postulated events. Estimates for initiating-event frequencies and consequences are generally conservative. Consistent with the requirements of DOE-STD-3009-2014, hazard event consequences are evaluated against the evaluation guideline (EG) of 25 rem to the maximally exposed offsite individual (MOI) and 100 rem to the co-located worker (CW) for the selection and safety classification of controls. Controls for moderate radiological consequences (5 rem to the MOI and 25 rem to the CW) are also considered. Risk bins are assigned based on the combination of frequency and consequences consistent with DOE-STD-3009-2014. Chemical hazards were appropriately screened out due to having no potential for significant health effects on workers or the MOI. For most events, the selection of controls for worker safety is adequate based on the criteria in DOE-STD-1189-2016.

As proposed in the last revision of the U1a Complex ECSE safety design strategy approved by NFO, the ECSE PDSA uses an alternate onsite atmospheric dispersion factor (χ/Q) for CW consequence determination that is based on a receptor distance of 3,500 meters from the point of release. This value corresponds to the distance of the nearest permanent structures, located in the Area 6 Construction Facilities. The PDSA treats all other workers as facility workers (FWs), contrary to DOE-STD-3009-2014, which defines an FW as a worker within the facility boundary and located less than 100 meters from the release point. Section 3.3.2 of DOE-STD-3009-2014 allows existing facilities to determine CW consequences at receptor distances farther than 100 meters for mitigated analysis if doing so is consistent with the actual location of adjacent facilities and if no viable control strategy exists that could reduce risk (in this case, to Risk Bin III or IV). Using the alternate CW location at 3,500 meters reduces dose consequences to less than 100 rem. The ECSE Project inappropriately uses this result to justify the application of less restrictive seismic design criteria.

DOE standards use consequences at various distances from potential radiological releases, providing perspective on the risks associated with a facility in order to facilitate hazard categorization, hazard control classification, and specification of design criteria. DOE-STD-3009-2014 establishes dose consequence thresholds at specified distances for classification of hazard controls. Section 3.3.2 states, "[A] conservatively calculated unmitigated dose of 100 rem [total effective dose] to a receptor located at 100 meters from the point of release shall be used as the threshold for designation of [safety significant] controls." The receptor distance is not to be changed for unmitigated dose calculation. The designation of CW is not tied to any specific role, responsibility, or level of training.

The PDSA provides a brief discussion justifying the use of the alternate CW location, stating, in part, "[T]here is no viable alternative control strategy that supports the mission." However, EA determined that the ECSE Project does not meet the conditions specified in DOE-STD-3009-2014 that allow for the use of an alternate dispersion factor based on a CW receptor distance more than 100 meters from the point of release. (See **Deficiency D-MSTS-1**.) The DOE-STD-3009-2014 provision applies only to existing facilities, not to major modifications of existing facilities. In safety basis standards and handbooks (e.g., DOE-HDBK-1224-2018, *Hazard and Accident Analysis Handbook*), when there is the need to distinguish between the application of the requirements based on the facility status, major modifications to existing facilities are grouped with new facilities, not existing facilities. However, even if the provision were to apply, the PDSA would need to establish that there are no viable control strategies. The PDSA proposes a safety improvement plan to perform structural analysis of the U1h Hoist Structure, U1a.01 Drift, and U1a.100 Drift Structure that could mitigate the risk from a seismic event. This analysis could lead to structural improvements that would constitute a viable control strategy. Also, increasing the CW receptor distance does not reduce accident risks to acceptable thresholds (i.e., several events remain in Risk Bin II for the CW at 3,500 meters), which is a condition for using the alternate CW location provision of DOE-STD-3009-2014. Application of the alternate dispersion factor results in underestimation of CW consequences (of what would be determined at 100 meters) as moderate instead of high, non-conservative seismic design criteria, and potentially inadequate controls for two explosion events (discussed in the Hazard Controls section below).

The Defense Nuclear Facilities Safety Board identified a similar concern about changing the CW receptor distance, described in the Staff Report, *Alternate Location for the Co-Located Worker at the U1a Complex,* July 30, 2021. The Board's concerns are related to the inapplicability of the DOE-STD-3009-2014 provisions to a major modification and the presence of facilities less than 3,500 meters from the point of release. The report recommends completing an initiative (identified in the PDSA as a planned design and operational improvement) to evaluate a more robust shipping container for SCEs. This initiative or consideration of other preventive designs (e.g., Type B packages) could provide a viable control strategy for protecting radioactive material from a variety of insults, including seismically initiated events.

Accident Analysis

The accident analysis in the PDSA is performed for hazard events that have the potential to challenge the EG. The accident analysis adequately evaluates an appropriate set of representative and unique design basis accidents (DBAs) derived from the hazard evaluation. For each DBA, the accident analysis provides an adequate discussion of scenario development, source term, initiating frequency, radiological consequences, comparison to consequence thresholds, and control selection, including identification of safety function and defense-in-depth features. The bounding radiological consequence DBA is a seismically initiated explosion. The radiological consequences for this event are 14.6 rem to the MOI and 83.7 rem to the CW. All fire, loss of confinement, and direct radiation exposure events result in low consequences to the MOI and CW. The lower dispersion factor for the alternate location reduces the calculated consequences for the CW by a factor of 47 (3,900 rem to 83.7 rem) from what would be obtained using the dispersion factor specified in DOE-STD-3009-2014.

The consequence analysis methodology and associated parameters are conservative for the MOI but not for the CW due to the assumed location of 3,500 meters. For events in which the radiological consequences challenge the EG, the PDSA appropriately justifies not designating safety class controls due to the conservatism in the determination of the dose to the MOI. Safety significant structures, systems, and components (SSCs) and specific administrative controls (SACs) are identified for DBAs based on the frequencies and consequences. Except for three seismic and two operational events, the control strategy appropriately results in a release frequency that is beyond extremely unlikely (BEU) for high and moderate consequence events (Risk Bins III and IV). The PDSA appropriately identifies an underground complex fire and an underground collapse as beyond design basis accidents. Since the maximum MAR was already assumed in high explosive violent reaction and fire events, more severe consequences than those determined for DBAs are not possible.

Hazard Controls

The PDSA identifies controls for protecting workers from potential hazard events, exclusive of standard industrial hazards addressed by existing safety management programs. Safety significant SSCs and SACs are appropriately identified for preventing or mitigating DBAs with consequences that challenge 25 rem to the MOI or exceed 25 rem to the CW and for protecting the FW.

The unmitigated consequences of fire events are low to the MOI and CW. For the FW, unmitigated consequences are high except for events occurring post-execution and during entombment, when they are moderate. The Radioactive Material and High Explosive Inventory Control SAC limits the quantities and forms of these materials to limit consequences. Most fire events are reduced to BEU by a suite of preventive controls that includes fire barriers, a fire extinguishing system, a fire detection system, and Fissile Material Containers (FMCs). A combination of preventive and mitigative controls reduce the risk of the remaining events (post-execution and entombment) for the FW. Evaluations generally demonstrate that the safety functional requirements of the controls can be met. However, the analysis of the postulated vehicle fire at the collar area is insufficient for deriving the performance criteria for the FMC. (See **Deficiency D-MSTS-2**.) The supporting fire analysis does not include sufficient information about the fire (e.g., size, duration, heat release) to evaluate the thermal exposure to the FMC. An inadequate fire analysis may result in performance criteria that cannot ensure the FMC will maintain its integrity during a fire.

The unmitigated consequences for the most significant explosion events are moderate to the MOI and CW and high to the FW. The mitigated likelihood of most explosion events is appropriately reduced to BEU by a suite of preventive controls that includes the SCE Container, zero room anchors, zero room structure, and fire prevention controls. For the tooling impact explosion and a fire-induced pre-execution explosion (in vessel, post-button-up), the mitigated consequences to the MOI and CW are shown as moderate in the PDSA, but they would be high to the CW if the consequences were calculated at 100 meters. For the tooling impact explosion event, FW consequences cannot be reduced because the operations require hands-on activities. Project procedures and safety requirements reduce the likelihood of an explosion event initiated by mechanical impact, but the credit for human reliability is limited, so mitigated risk for the FW remains in Risk Bin II. The SER contains a condition of approval (COA) (see section 3.2) to provide rigorous justification that there are no viable controls available to reduce the risk.

Unmitigated consequences for loss of confinement events are low or moderate to the MOI, CW, and FW except for post-execution events and an event involving failure of the vessel confinement system, which have moderate consequences to the FW. These events are adequately mitigated by a suite of controls that includes the Accelerator Sweep and Secure and Reentry Practices SACs.

Wind, lightning, and range fire events result in unmitigated moderate consequences to the MOI and CW and high consequences to the FW. The mitigated likelihood of these events is reduced to BEU by controls that include FMCs and the SCE Container. Consequences from loss of confinement events due to seismic initiation are low to all receptors. Seismically induced explosions in the collar, shaft, and drift have unmitigated risk in Risk Bin I (FW) and Risk Bin II (CW and MOI); the risk remains unchanged after the application of controls. The PDSA acknowledges the residual risk and justifies risk acceptance based on the conservatism in the determination of the consequences (e.g., leak path factor of one) and frequency (e.g., not considering the short duration of the ECSE operations).

Most of the hazard events are mitigated to Risk Bin IV for the CW regardless of whether the CW distance is assumed to be 3,500 or 100 meters. Other than the two explosion and three seismic events (which result in explosions in the collar, shaft, and drift), using an alternate CW location does not impact the adequacy of the control sets. The lack of controls for the tooling event to mitigate the risk to the FW is not related to the application of the alternate dispersion factor as discussed above. The two explosion events have moderate unmitigated consequences to the CW and are not mitigated to BEU. Application of the dispersion factor at 100 meters would increase the consequences to high for the CW, potentially impacting control selection.

Except for the five events described above, hazard controls are properly identified and selected with clear traceability to the hazard events, and the safety functions and associated functional requirements are identified. The selection of hazard controls follows the DOE-STD-1189-2016 preferred control hierarchy, and the controls are generally adequate to prevent or mitigate the analyzed hazards.

Defense-in-Depth

The PDSA effectively incorporates the principles of defense-in-depth described in DOE-STD-1189-2016. SSCs and administrative controls provide multiple independent barriers to protect workers and the public from postulated hazard events. The barriers include credited and non-credited controls.

3.1.4 Structures, Systems, and Components and Specific Administrative Controls

EA assessed the evaluations of hazard controls to determine whether the safety functions, functional requirements, and performance criteria are adequate.

Safety Structures, Systems, and Components

The safety functions, functional requirements, and performance criteria for SSCs are clearly described in the PDSA and allow evaluation of the controls to determine whether they effectively prevent or mitigate DBAs. The safety functions are consistent with those identified in the hazard and accident analyses. The functional requirements and system evaluations support a sufficient understanding of how the SSCs satisfy their safety functions. The nuclear safety design criteria of DOE Order 420.1C are adequately addressed. Controls are appropriately classified as safety significant because the unmitigated consequences for all events are less than 25 rem to the MOI.

Specific Administrative Controls

The PDSA identifies SACs to protect initial conditions, preserve analysis assumptions, or prevent hazardous events. Three new SACs support accelerator operation and one supports button-up activities. The controls are appropriately identified as SACs because the functions could not reasonably be performed by SSCs. For each SAC, the PDSA provides the safety functions, description, and functional requirements. The PDSA also includes an evaluation section that adequately assesses the ability of each SAC to meet its identified safety function. The SACs are sufficiently established to support the PDSA and final design. The safety functions of the SACs are consistent with those identified in the hazard analysis and provide adequate protection.

3.1.5 Preliminary Derivation of Technical Safety Requirements

EA evaluated the preliminary derivation of TSRs in the PDSA to verify accurate translation of performance requirements for credited SSCs and SACs into a set of formal, implementable requirements. The preliminary derivation of TSRs meets the requirements of DOE-STD-1189-2016. Six facility modes—cold and warm standby, and four modes related to accelerator status—are established with adequate descriptions. Safety functions and associated surveillances for preliminary limiting conditions for operation (LCOs) are identified and adequately described. Design features are adequately described, and SACs are appropriately written as either directive action administrative controls or LCOs.

Conclusion

The PDSA generally meets the requirements of DOE-STD-1189-2016 and DOE-STD-3009-2014. The PDSA and associated references provide adequate site and facility information for understanding hazards associated with ECSE operations and supporting the safety analysis. Except for the hazard events noted in section 3.1.3 and as described in the deficiencies above, the PDSA adequately identifies and evaluates the hazards associated with the ECSE Project. Safety functions and functional requirements for SSCs and SACs are sufficiently defined to meet the hazard control requirements derived in the hazard analysis. The evaluation of SSCs and SACs demonstrates that safety functions can be met. The identified operational modes, LCOs, and design features are adequate to support the derivation of TSRs.

3.2 Federal Review and Approval

EA reviewed the SER to determine its adequacy as the approval basis for the PDSA as required by DOE-STD-1104-2016. The NFO safety basis review team (SBRT) used the lines of inquiry from the NFO-approved *Safety Basis Review Plan for the Enhanced Capabilities for the Enhanced Capabilities for Subcritical Experiments Project* to ensure the thoroughness of the review.

The SBRT included members with appropriate subject matter expertise in nuclear safety, criticality safety, and safety systems oversight. Upon concluding that all the DOE-STD-1104-2016 approval bases were met, the SBRT recommended approval of the U1a Complex ECSE PDSA, subject to the identified conditions of approval and identified requirements for a PDSA update.

The SER addresses the approval bases identified in DOE-STD-1104-2016, including verification that the design safety analysis is complete and demonstrates adequacy of the design from a safety perspective, that the hazard analysis is consistent with DOE-STD-1189-2016, and that the nuclear safety design criteria of DOE Order 420.1C are met. The SBRT identified eight COAs: four related to base information, two related to the hazard and accident analysis, and two related to safety SSCs. EA identified a concern about project vulnerabilities associated with the incomplete design of the fire extinguishing system; this concern is addressed in a COA. The SER identified six issues requiring resolution in the next PDSA revision.

The SER adequately documents review of the PDSA and provides an understanding of the DBA consequences and the controls incorporated into the ECSE design to prevent significant hazard events. The SER properly addresses the approval bases identified for review in DOE-STD-1104-2016. The SER does not provide an evaluation of the alternate CW location; however, the previous approval by NFO with concurrence from the Federal Project Director is referenced.

The SER meets the requirements of DOE-STD-1104-2016 and adequately documents the basis for approving the PDSA.

4.0 BEST PRACTICES

No best practices were identified during this assessment.

5.0 FINDINGS

No findings were identified during this assessment.

6.0 DEFICIENCIES

Deficiencies are inadequacies in the implementation of an applicable requirement or standard. Deficiencies that did not meet the criteria for findings are listed below, with the expectation from DOE Order 227.1A for site managers to apply their local issues management processes for resolution.

Mission Support and Test Services, LLC

Deficiency D-MSTS-1: The PDSA does not meet the conditions for using an alternate dispersion factor based on a co-located worker receptor distance more than 100 meters from the point of release. (DOE-STD-3009-2014, section 3.3.2)

Deficiency D-MSTS-2: The analysis of the postulated vehicle fire at the collar area is insufficient for deriving the performance criteria for the Fissile Material Container. (DOE-STD-3009-2014, section 3.4)

7.0 OPPORTUNITIES FOR IMPROVEMENT

No opportunities for improvement were identified during this assessment.

8.0 ITEMS FOR FOLLOW-UP

The following items for follow-up were identified as part of this assessment:

- Review the revised PDSA to verify that the correct dispersion factor is implemented and the resulting changes to the hazard analysis are incorporated.
- Verify that the analysis of the collar fire event is sufficient for validating the performance criteria for the FMC.

Appendix A
Supplemental Information

Dates of Assessment

October 2021 – May 2022

Office of Enterprise Assessments (EA) Management

John E. Dupuy, Director, Office of Enterprise Assessments
William F. West, Deputy Director, Office of Enterprise Assessments
Kevin G. Kilp, Director, Office of Environment, Safety and Health Assessments
David A. Young, Deputy Director, Office of Environment, Safety and Health Assessments
Kevin M. Witt, Director, Office of Nuclear Safety and Environmental Assessments
Kimberly G. Nelson, Acting Director, Office of Worker Safety and Health Assessments
Jack E. Winston, Director, Office of Emergency Management Assessments
Joseph J. Waring, Director, Office of Nuclear Engineering and Safety Basis Assessments

Quality Review Board

William F. West, Advisor
Kevin G. Kilp, Chair
Joseph Lewis
Karen Sims
Scott Wenholz
Michael A. Kilpatrick

EA Site Lead for Nevada National Security Site

Sarah C. R. Gately

EA Assessors

Daniel M. Schwendenman, Lead
Halim A. Alsaed
Kevin E. Bartling
Katherine S. Lehew
Jeffrey L. Robinson