

TOPICAL REPORT

**External and Internal Hazards Analysis and
Safety Basis Event Identification for SOLO™
Non-Power Reactor**

(Non-Proprietary)

Total Pages:45

Document Number: SOLO-TR-2025-11

Revision 0

(Enclosure 4)

2026-02-15

Terra Innovatum s.r.l.

Via Matteo Trenta 117, 55100 Lucca (LU), Italy

Notes on revisions, source control and e-attachments:

Revision 0

First release.

Signatures

Role	Person	Signature
Author	Cesare Frepoli	
Reviewer	Ivica Basic	
Approver	Cesare Frepoli	

Git commit

N/A

Archive Content (e-attachments)

None

Instructions

None.

STANDARD TERMS, ACRONYMS, AND DEFINITIONS

For convenience, Table 1 provides the definitions of common terms used in this section and Table 2 provides acronyms and abbreviations.

Table 1 – Acronyms and Abbreviations

Term	Definition
CFR	Code of Federal Regulations
DOE	U.S. Department of Energy
FSAR	Final Safety Analysis Report
I&C	Instrumentation and Control
IRC	Integrated Radiological Containment
LEU	Low-Enriched Uranium
MHA	Maximum Hypothetical Accident
NRC	U.S. Nuclear Regulatory Commission
PSAR	Preliminary Safety Analysis Report
PTCS	Pressure Tubes Coolant System
SBE	Safety Basis Event
SSC	Structure, System, or Component

EXECUTIVE SUMMARY

This Topical Report documents the systematic hazards analysis and identification of Safety Basis Events (SBEs) for the SOLO FOAK, a 5 MWth, helium-cooled, thermal-spectrum test reactor utilizing commercially available low-enriched uranium (LEU) UO₂ fuel. The report establishes a complete and traceable set of bounding accident scenarios that define the deterministic safety analysis envelope for licensing under 10 CFR Part 50 as a Class 104 non-power reactor.

The analysis is performed using a structured, deterministic methodology consistent with:

- NUREG-1537, Guidelines for Preparing and Reviewing Applications for the Licensing of Non-Power Reactors;
- DOE-HDBK-1224-2024, Hazard and Accident Analysis Handbook; and
- DOE-HDBK-1163-2020, Nuclear Safety Basis Development.

The approach proceeds in a logical progression:

1. Identification of hazard sources, defined as sources of energy or radioactive material internal to the facility;
2. Identification of initiating events, including internal failures and external phenomena that act upon those hazard sources;
3. Development and consolidation of representative accident scenarios;
4. Selection of limiting events within each applicable NUREG-1537 accident category; and
5. Identification of a Maximum Hypothetical Accident (MHA) for bounding radiological consequence evaluation.

The SOLO FOAK safety framework is organized around three fundamental safety functions:

- Removal of heat from the reactor;
- Confinement of radioactive material; and
- Control of reactivity and safe shutdown.

All identified hazards and initiating events are evaluated with respect to their potential to challenge these safety functions. No initiating events are screened out based on probability.

Limiting events are selected deterministically within each applicable NUREG-1537 accident category, including insertion of excess reactivity, loss of coolant, loss of coolant flow, fuel malfunction, experiment malfunction (as applicable), loss of normal electrical power, external events, and equipment malfunction.

The Maximum Hypothetical Accident is defined as the immediate failure of the central fuel assembly of the reactor core. With nineteen fuel assemblies in the SOLO core, this corresponds to approximately seven percent of the total core radioactive inventory. The assumption of immediate failure introduces additional conservatism and provides a bounding construct for radiological consequence evaluation.

The MHA is distinct from the analyzed Safety Basis Events. While SBEs are evaluated against defined acceptance criteria or surrogate figures of merit to demonstrate system performance, the MHA assumes a more severe damage state to ensure conservative bounding of potential radiological consequences. This layered approach reinforces defense-in-depth within the SOLO safety case.

The results of this report demonstrate that:

- all credible internal and external accident initiators have been systematically identified;

- all fundamental safety functions are challenged and addressed within the SBE set;
- limiting events have been selected in accordance with NUREG-1537; and
- a bounding Maximum Hypothetical Accident has been defined for consequence evaluation.

Accordingly, this Topical Report establishes a complete, traceable, and technically defensible accident set that supports deterministic accident analyses in the PSAR and FSAR and provides the foundation for subsequent SSC safety classification and licensing evaluations.

TABLE OF CONTENTS

EXECUTIVE SUMMARY	4
1 Introduction and Regulatory Context	10
1.1 Purpose of the Topical Report	10
1.2 Regulatory Basis and Guidance	10
1.3 Definitions and Analytical Conventions	11
1.4 Facility Scope and Interfaces	12
1.5 Relationship to the Overall SOLO Licensing Basis.....	12
1.6 Organization of This Report	12
2 Safety Functions and Design Safety Philosophy	14
2.1 Role of Safety Functions in Hazard and Event Identification.....	14
2.2 Fundamental Safety Functions.....	14
2.2.1 Removal of Heat from the Reactor.....	14
2.2.2 Confinement of Radioactive Material	14
2.2.3 Control of Reactivity and Safe Shutdown	14
2.3 Deterministic Safety Function Success Criteria.....	15
2.3.1 Removal of Heat from the Reactor.....	15
2.3.2 Confinement of Radioactive Material	15
2.3.3 Control of Reactivity and Safe Shutdown	15
2.4 Safety Philosophy and Defense-in-Depth Strategy.....	15
2.5 Design Attributes Relevant to Hazard and Event Screening	16
2.6 Treatment of Operator Actions	16
2.7 Linkage to Accident Categories and Subsequent Analyses	16
3 Hazard Identification	17
3.1 Purpose of Hazard Identification	17
3.2 Hazard Identification Methodology.....	17
3.3 Operating Modes and Configurations Considered.....	17
3.4 Hazard Sources	17
3.4.1 Nuclear Heat and Decay Heat	18
3.4.2 Stored Thermal Energy	18
3.4.3 Pressure Energy.....	18
3.4.4 Radioactive Material Inventory.....	18
3.4.5 Reactivity and Neutron Kinetics	18
3.4.6 Electrical and Mechanical Energy.....	18
3.5 Internal and External Hazard Treatment.....	18
3.5.1 Internal Initiating Hazards.....	18
3.5.2 External Initiating Hazards.....	19
3.5.3 Treatment of Initiating Hazards in Accident Identification.....	19
3.6 Hazard Register.....	19
3.7 Relationship Between Hazards and Safety Functions.....	19

3.8	Transition to Initiating Event Identification.....	20
4	Initiating Event Development and Accident Categorization.....	21
4.1	Purpose of Initiating Event Identification.....	21
4.2	Initiating Event Identification Methodology.....	21
4.3	Treatment of Internal and External Initiators.....	21
4.4	Initiating Event Categories	22
4.4.1	Loss or Degradation of Heat Removal	22
4.4.2	Reactivity Control and Shutdown Malfunctions	22
4.4.3	Confinement and Boundary Degradation	22
4.4.4	Loss of Electrical Power or Support Functions.....	22
4.4.5	External Event–Initiated Conditions	23
4.5	Initiating Event List	23
4.6	Mapping of Initiating Events to NUREG-1537 Chapter 13 Accident Categories	23
5	Event Screening, Consolidation, and Scenario Development.....	25
5.1	Purpose of Event Screening and Scenario Development.....	25
5.2	Scenario Development Approach	25
5.3	Screening and Consolidation Principles	25
5.4	Relationship to NUREG-1537 Accident Categories.....	26
5.5	Output of Chapter 5	26
5.6	Representative Accident Scenarios by NUREG-1537 Accident Category.....	26
5.6.1	Insertion of Excess Reactivity	26
5.6.2	Loss of Coolant	26
5.6.3	Loss of Coolant Flow	27
5.6.4	Mishandling or Malfunction of Fuel	27
5.6.5	Experiment Malfunction.....	27
5.6.6	Loss of Normal Electrical Power	27
5.6.7	External Events.....	28
5.6.8	Mishandling or Malfunction of Equipment.....	28
5.6.9	Summary of Representative Accident Scenarios.....	28
6	Selection of Limiting Events by Accident Category.....	29
6.1	Purpose and Approach for Limiting Event Selection	29
6.1.1	Deterministic Selection Basis.....	29
6.1.2	Bounding Considerations	29
6.1.3	Treatment of Non-Applicable Categories	29
6.1.4	Relationship to Maximum Hypothetical Accident Selection	29
6.1.5	Output of Chapter 6.....	29
6.2	Definition of a Limiting Event.....	30
6.2.1	Insertion of Excess Reactivity	30
6.2.2	Loss of Coolant	30
6.2.3	Loss of Coolant Flow	30
6.2.4	Mishandling or Malfunction of Fuel	30

6.2.5	Experiment Malfunction.....	30
6.2.6	Loss of Normal Electrical Power	30
6.2.7	External Events.....	31
6.2.8	Mishandling or Malfunction of Equipment.....	31
6.2.9	Summary	31
7	Maximum Hypothetical Accident Definition Basis	32
7.1	Purpose and Basis of the Maximum Hypothetical Accident	32
7.1.1	Deterministic and Bounding Basis	32
7.1.2	Relationship to Safety Basis Event Analyses.....	32
7.1.3	Scope of This Chapter	32
7.2	Identification of the Maximum Hypothetical Accident	33
7.2.1	Basis for Selection.....	33
7.2.2	Conservatism and Defense-in-Depth.....	33
8	Final Safety Basis Event Set and Conclusions	34
8.1	Purpose of This Chapter.....	34
8.2	Summary of Methodology	34
8.3	Final Safety Basis Event Set.....	34
8.4	Relationship Between SBEs and the Maximum Hypothetical Accident	35
8.5	Completeness of the Accident Set	35
8.6	Interface with Subsequent Licensing Analyses	35
8.7	Conclusions.....	36
9	References	37
Appendix A - Hazard Identification, Screening, and Hazard Register.....		38
A.1	Purpose and Role of Appendix A	38
A.2	Hazard Identification Screening Approach	38
A.3	Hazard Source Identification (Energy and Material at Risk).....	38
A.3.2	Hazard Source Identification Table	39
A.4	Initiating Hazard Applicability Screening	39
A.4.1	Purpose.....	39
A.4.2	Initiating Hazard to Hazard Source Association	39
A.5	Hazard Register	40
A.5.1	Purpose.....	40
A.5.2	Hazard Register Table.....	40
A.6	Relationship to Initiating Event Identification.....	42
A.7	Summary and Completeness Statement.....	42
Appendix B - Initiating Event Identification and Master List.....		43
B.1	Purpose and Scope.....	43
B.2	Initiating Event Identification Process.....	43
B.2	Initiating Event Master List.....	43
B.4	Relationship to Accident Scenario Development	44

B.5	Relationship to Safety Basis Event Selection.....	45
B.6	Completeness and Consistency Statement.....	45

1 INTRODUCTION AND REGULATORY CONTEXT

1.1 PURPOSE OF THE TOPICAL REPORT

This Topical Report documents the hazards analysis and identification of Safety Basis Events (SBEs) for the SOLO FOAK. The purpose of this report is to systematically identify hazard sources, initiating events, and representative accident scenarios that bound credible challenges to the facility's fundamental safety functions, and to establish the event set that forms the basis for subsequent deterministic accident analyses.

Specifically, this report:

- identifies and characterizes hazard sources, defined as sources of energy or radioactive material associated with the SOLO FOAK that could challenge fundamental safety functions if uncontrolled;
- identifies credible initiating events, including internal failures and external phenomena, that act upon hazard sources and initiate accident sequences;
- develops accident scenarios linking initiating events to challenges to safety functions;
- screens, consolidates, and groups scenarios into representative Safety Basis Events;
- selects limiting events within recognized accident categories; and
- establishes the basis for the Maximum Hypothetical Accident (MHA) selection.

This report does not perform detailed quantitative accident consequence analyses, dose calculations, or acceptance-criteria evaluations. Those analyses are performed in the Preliminary Safety Analysis Report (PSAR) and Final Safety Analysis Report (FSAR), consistent with NUREG-1537 [1], *Guidelines for Preparing and Reviewing Applications for the Licensing of Non-Power Reactors*, Chapter 13.

In addition, this report does not classify structures, systems, and components (SSCs). SSC classification is addressed in a separate deterministic SSC Safety Classification Topical Report that relies on the SBEs identified herein, consistent with a graded safety basis development approach as described in DOE-HDBK-1163-2020 [2].

1.2 REGULATORY BASIS AND GUIDANCE

The SOLO FOAK is being licensed as a Class 104 test reactor under 10 CFR Part 50. The regulatory expectations for accident identification and analysis are defined primarily by NUREG-1537. In particular, NUREG-1537 Part 1, Chapter 13 describes the expected content of accident analyses, and NUREG-1537 Part 2, Chapter 13 describes the staff review process and acceptance criteria. These chapters explicitly expect the applicant to demonstrate that:

- all potential accident types have been systematically considered;
- accidents are grouped into recognized categories;
- a limiting event is identified within each applicable category;
- a Maximum Hypothetical Accident is identified that bounds credible accidents; and
- quantitative probability analysis is not required for accident selection or evaluation.

This Topical Report implements those expectations by providing the systematic accident identification and selection basis that supports Chapter 13 accident analyses.

To support a structured and traceable approach to hazards analysis and accident identification, this report employs the methodology described in DOE-HDBK-1224-2024 [3], *Hazard and Accident Analysis Handbook*. DOE-HDBK-1224-2024 is used strictly as methodological guidance for identifying hazard sources, developing and screening accident scenarios, grouping events, and demonstrating completeness. It is not used as a regulatory standard or acceptance-criteria document.

In addition, this report is structured consistent with the graded safety basis development principles described in DOE-HDBK-1163-2020 [2], *Nuclear Safety Basis Development*, which emphasize the systematic progression from hazards identification to accident analysis and, subsequently, to identification of safety functions and controls.

The integrated, function-based relationship between hazards, accident sequences, and safety functions described in NUREG-1513, *Integrated Safety Analysis Guidance Document*, is also used as conceptual guidance to support a clear and traceable hazards and accident identification process. NUREG-1513 is not used as a regulatory framework for acceptance.

Accordingly, the approach adopted in this report may be summarized as follows:

Hazards analysis and accident identification are performed using a systematic, deterministic methodology consistent with DOE-HDBK-1224-2024 and DOE-HDBK-1163-2020, informed by the integrated safety analysis principles described in NUREG-1513, and the results are organized and presented in a manner consistent with the accident categorization and evaluation expectations of NUREG-1537 Chapter 13.

1.3 DEFINITIONS AND ANALYTICAL CONVENTIONS

For clarity and consistency, this Topical Report adopts specific definitions and analytical conventions regarding the use of the term *hazard*. These conventions are established at the outset to ensure a clear, systematic, and traceable hazards and accident identification process.

Hazard Source

For the purposes of this report, a *hazard source* is defined as a source of energy or radioactive material internal to the facility that, if released, mobilized, or uncontrolled, could challenge one or more fundamental safety functions. Hazard sources include, but are not limited to, nuclear and decay heat, stored thermal energy, pressure energy, radioactive material inventory, and reactivity.

This definition is consistent with the use of the term *hazard* in DOE-HDBK-1224-2024 and DOE-HDBK-1163-2020, which define hazards in terms of energy or material capable of causing harm if not adequately controlled.

Initiating Hazard / Initiating Event

An *initiating hazard* or *initiating event* is an internal failure or external phenomenon that acts upon a hazard source and initiates an accident sequence. Initiating events may include internal equipment failures, human actions, fires, seismic events, loss of power, or other external or internal disturbances.

In this context, external events such as fires, earthquakes, or man-made hazards are not themselves hazard sources; rather, they are mechanisms that can lead to the release, mobilization, or loss of control of hazard sources.

Analytical Convention Used in This Report

Consistent with DOE-HDBK-1224-2024, DOE-HDBK-1163-2020, and the integrated safety analysis principles described in NUREG-1513, this Topical Report:

- identifies hazard sources first (energy and radioactive material);
- then identifies initiating events, both internal and external, that act upon those hazard sources; and

- evaluates accident scenarios based on their potential to challenge the facility's fundamental safety functions.

Accident categorization, presentation, and acceptance are performed in accordance with NUREG-1537, Chapter 13.

1.4 FACILITY SCOPE AND INTERFACES

The scope of this report includes hazard sources, initiating events, and accident scenarios associated with the SOLO FOAK reactor module and associated systems that are relevant to nuclear safety. The scope encompasses:

- reactor core and internal structures;
- primary coolant and heat removal functions;
- confinement and shielding features;
- interfaces necessary for heat rejection that influence accident progression; and
- internal and external initiating events that could credibly affect reactor safety functions.

This report focuses on radiological safety and the identification of accident scenarios that could challenge the facility's fundamental safety functions. Security-related events, safeguards considerations, and emergency response planning details are addressed in separate licensing documents and are not within the scope of this report.

1.5 RELATIONSHIP TO THE OVERALL SOLO LICENSING BASIS

This Topical Report occupies a defined position within the SOLO FOAK licensing basis and interfaces with other licensing submittals as follows:

- **PSAR/FSAR Chapter 13 (Accident Analyses):**
The Safety Basis Events (SBEs), limiting events, and Maximum Hypothetical Accident (MHA) identified in this report define the accident scenarios that are analyzed quantitatively in Chapter 13, consistent with NUREG-1537, Chapter 13.
- **SSC Safety Classification Topical Report:**
The SBEs identified herein provide the event and functional basis for determining which structures, systems, and components (SSCs) are required to perform fundamental safety functions during accident conditions and for supporting deterministic SSC safety classification, consistent with a graded safety basis development approach.
- **Emergency Planning and Siting Evaluations:**
The bounding events identified in this report inform evaluations of radiological consequences and emergency planning and siting considerations, where applicable.

This Topical Report therefore serves as the front-end analytical foundation for multiple downstream safety and licensing analyses within the SOLO FOAK licensing basis.

1.6 ORGANIZATION OF THIS REPORT

This Topical Report is organized as follows:

- **Chapter 1** describes the purpose, regulatory context, scope, definitions, and role of the report within the SOLO FOAK licensing basis.
- **Chapter 2** defines the fundamental safety functions and design safety philosophy that guide hazard screening and event selection.

- **Chapter 3** identifies hazard sources, defined as sources of energy or radioactive material associated with the SOLO FOAK, and establishes a traceable hazard register.
- **Chapter 4** identifies initiating events, including internal failures and external phenomena, and maps them to recognized accident categories consistent with NUREG-1537, Chapter 13.
- **Chapter 5** describes event screening, consolidation, and accident scenario development.
- **Chapter 6** documents the selection of limiting events within each applicable accident category.
- **Chapter 7** establishes the basis for selection of the Maximum Hypothetical Accident (MHA).
- **Chapter 8** defines the final Safety Basis Event (SBE) set and demonstrates completeness and adequacy.
- **Appendices** provide supporting tables, registers, and traceability matrices.

This organization provides a logical progression from hazard source identification, through initiating event and accident scenario development, to selection of bounding events, and ensures clear alignment with NRC expectations for deterministic accident analysis of test reactors.

Figure 1 shows a rendering a possible future SOLO site with three modules. Note that the current licensing application is for a single unit.



Figure 1: SOLO Microreactor Site with Three Units (Layout Rendering)

2 SAFETY FUNCTIONS AND DESIGN SAFETY PHILOSOPHY

2.1 ROLE OF SAFETY FUNCTIONS IN HAZARD AND EVENT IDENTIFICATION

The identification, screening, and selection of Safety Basis Events (SBEs) for the SOLO FOAK are anchored in the facility's fundamental safety functions. Safety functions define the essential objectives that must be preserved to protect the health and safety of workers and the public under normal operation, anticipated operational occurrences, and accident conditions.

Consistent with NUREG-1537 Chapter 13, accident scenarios are evaluated and grouped based on how they challenge these safety functions. Consistent with DOE-HDBK-1224-2024, safety functions provide the organizing framework for hazard identification, initiating-event development, scenario screening, grouping, and completeness demonstration.

By establishing the safety functions at the outset, this report ensures that hazard identification and event selection are systematic, traceable, and deterministic, and that subsequent selection of limiting events and the Maximum Hypothetical Accident (MHA) is grounded in clearly defined safety objectives.

2.2 FUNDAMENTAL SAFETY FUNCTIONS

For the purposes of hazards analysis, initiating-event identification, and Safety Basis Event selection, the SOLO FOAK relies on **three fundamental safety functions**. These functions define the minimum conditions necessary to maintain nuclear safety and are independent of specific structures, systems, or components.

The three fundamental safety functions are described next. These three fundamental safety functions provide the sole organizing framework for hazard identification, initiating-event screening, accident scenario grouping, and selection of limiting events in this report. Each Safety Basis Event identified in later chapters explicitly identifies which of these safety functions are challenged.

2.2.1 Removal of Heat from the Reactor

The capability to remove heat generated in the reactor core under all operating and accident conditions, including the removal of fission heat during power operation and the removal of decay heat following reactor shutdown over both short-term and long-term time frames.

This safety function ensures that fuel, moderator, and structural temperatures remain within acceptable limits and that degradation of fuel integrity or structural performance is prevented. Events that degrade or prevent effective heat removal are evaluated as potential Safety Basis Events.

2.2.2 Confinement of Radioactive Material

The capability to confine radioactive material within defined physical barriers and to limit the release of radionuclides to the environment during accident conditions.

This safety function encompasses the performance of the fuel form, coolant boundary, confinement structures, and associated barriers relied upon to retain radioactive material. Events that challenge the integrity of these barriers or create credible release pathways are evaluated as potential Safety Basis Events.

2.2.3 Control of Reactivity and Safe Shutdown

The capability to control reactor reactivity during all operating modes, terminate the nuclear chain reaction when required, and maintain the reactor in a subcritical condition under accident conditions.

This safety function includes both the prevention of unintended reactivity excursions and the assurance of reliable reactor shutdown. Events that could lead to reactivity insertion, failure to shutdown, or recriticality are evaluated as potential Safety Basis Events.

2.3 DETERMINISTIC SAFETY FUNCTION SUCCESS CRITERIA

For the purpose of hazard identification and event selection, qualitative success criteria are defined for each fundamental safety function. These criteria are used to determine whether an event challenges a safety function and to support screening and bounding decisions. Quantitative limits and acceptance criteria are applied in subsequent accident analyses and are not defined in this report.

2.3.1 Removal of Heat from the Reactor

Successful performance of the heat-removal safety function is defined as:

- maintenance of fuel, moderator, and structural temperatures below levels that would compromise fuel integrity or structural performance; and
- the ability to remove decay heat over extended time periods without reliance on extraordinary operator actions.

2.3.2 Confinement of Radioactive Material

Successful performance of the confinement safety function is defined as:

- maintenance of the integrity of physical barriers relied upon to retain radioactive material; and
- limitation of radioactive releases such that radiological consequences remain within acceptable bounds.

Radiation shielding is treated as an attribute supporting confinement, rather than as a separate safety function.

2.3.3 Control of Reactivity and Safe Shutdown

Successful performance of the reactivity control and shutdown safety function is defined as:

- termination of the nuclear chain reaction within a time frame consistent with design intent; and
- prevention of inadvertent recriticality following shutdown under accident conditions.

2.4 SAFETY PHILOSOPHY AND DEFENSE-IN-DEPTH STRATEGY

The SOLO FOAK safety philosophy emphasizes accident prevention through inherent design characteristics and accident mitigation through passive features and defense-in-depth. This philosophy directly informs hazard screening, event grouping, and selection of bounding scenarios.

Key elements of this philosophy include:

- **Low thermal power (5 MWth)**, limiting stored energy and decay heat;
- **Inherent reactivity feedbacks** that oppose power excursions;
- **Diverse shutdown mechanisms** to ensure reliable reactivity control;
- **Passive heat-removal pathways**, reducing reliance on active systems and operator action; and
- **Multiple physical barriers** for radionuclide confinement, including the fuel form, the cladding, solid moderator buffering, coolant channels (PTCS) physically separated from fuel pins, confinement structures (Integrated Radiological Containment, IRC), and shielding (the Monolith)

Defense-in-depth is achieved through a combination of inherent characteristics, passive design features, engineered systems, and administrative controls. No single feature is assumed to be solely responsible for maintaining safety.

2.5 DESIGN ATTRIBUTES RELEVANT TO HAZARD AND EVENT SCREENING

This report is not intended to provide a comprehensive design description. However, certain design attributes of the SOLO FOAK are directly relevant to hazard identification and event screening and are summarized here to support later analysis:

- the limited radionuclide inventory associated with a 5 MWth test reactor;
- the use of an inert coolant, eliminating chemical reactivity hazards;
- physical separation between fuel and primary coolant
- the absence of large stored coolant inventories or phase-change phenomena;
- the availability of passive heat-removal mechanisms under accident conditions; and
- robust structural and shielding features that influence accident consequences.

These attributes inform the identification of credible hazards and the bounding of accident scenarios in later chapters.

2.6 TREATMENT OF OPERATOR ACTIONS

For the purposes of hazard identification and Safety Basis Event selection, [[
]] for the successful performance of the fundamental safety functions unless explicitly stated. This conservative assumption ensures that the identified SBEs bound accident scenarios without reliance on timely or complex human actions.

[[

]]

2.7 LINKAGE TO ACCIDENT CATEGORIES AND SUBSEQUENT ANALYSES

The safety functions defined in this chapter provide the basis for:

- mapping initiating events to **NUREG-1537 Chapter 13 accident categories**;
- screening and grouping accident scenarios;
- selecting limiting events within each applicable category; and
- demonstrating completeness and adequacy of the final Safety Basis Event set.

By establishing a clear, three-function safety framework prior to hazard and event identification, this report ensures that the resulting SBE set provides comprehensive coverage of all credible challenges to reactor safety and supports subsequent deterministic accident analyses and SSC classification activities.

3 HAZARD IDENTIFICATION

3.1 PURPOSE OF HAZARD IDENTIFICATION

The purpose of hazard identification is to systematically identify sources of energy and material associated with the SOLO reactor that could, if uncontrolled, challenge the facility's fundamental safety functions and lead to accident conditions. Hazard identification provides the foundation for identifying initiating events, developing accident scenarios, and selecting Safety Basis Events (SBEs).

Consistent with DOE-HDBK-1224-2024, hazard identification is performed prior to initiating-event identification and scenario development and is used to ensure that all credible accident initiators are considered in a structured and traceable manner. Consistent with NUREG-1537 Chapter 13, this process supports the demonstration that all potential accident types have been systematically evaluated.

3.2 HAZARD IDENTIFICATION METHODOLOGY

Hazards for the SOLO FOAK are identified using a deterministic, hazards-analysis-driven approach, informed by functional review and "What-If" style evaluation consistent with DOE-HDBK-1224-2024.

Key elements of the hazard identification methodology include:

- review of reactor design features and operating modes;
- identification of material at risk (MAR) and sources of stored or generated energy;
- identification of credible mechanisms by which hazards could be released or mobilized;
- identification of safety functions that could be challenged by each hazard; and
- documentation of hazards in a structured hazard register to support traceability.

Hazards are identified without consideration of probability or frequency. Screening based on credibility, consequence potential, or bounding arguments is performed in later chapters.

3.3 OPERATING MODES AND CONFIGURATIONS CONSIDERED

Hazard identification considers the SOLO FOAK across all operating modes and configurations relevant to nuclear safety, including:

- normal steady-state operation at licensed power;
- startup and shutdown operations;
- low-power testing and surveillance conditions;
- short-term shutdown with elevated decay heat; and
- long-term shutdown and decay heat removal conditions.

Hazards associated solely with non-nuclear activities or configurations not relevant to accident progression are outside the scope of this report.

3.4 HAZARD SOURCES

Hazard sources are identified by considering sources of energy or radioactive material internal to the facility that could challenge one or more of the three fundamental safety functions defined in Section 2 if released, mobilized, or uncontrolled.

3.4.1 Nuclear Heat and Decay Heat

Nuclear fission and radioactive decay generate heat within the reactor core. Loss or degradation of heat removal capability could lead to elevated fuel, moderator, or structural temperatures, challenging the removal of heat from the reactor safety function.

3.4.2 Stored Thermal Energy

Thermal energy stored in the fuel, moderator, structural materials, and surrounding components represents a hazard source if not adequately dissipated following reactor shutdown. This hazard source is closely coupled to decay heat and influences accident progression following loss of normal cooling.

3.4.3 Pressure Energy

Pressurized volumes within the reactor coolant and associated systems contain stored pressure energy. Failure or degradation of pressure boundaries could affect heat removal performance and create pathways for radioactive material release, challenging both the removal of heat from the reactor and confinement of radioactive material safety functions.

3.4.4 Radioactive Material Inventory

Radioactive material is present primarily within the reactor fuel and, to a lesser extent, within the coolant and system surfaces. Mobilization or release of this material due to fuel damage, boundary failure, or confinement degradation challenges the confinement of radioactive material safety function.

3.4.5 Reactivity and Neutron Kinetics

Reactivity control mechanisms and neutron kinetics represent a hazard if positive reactivity is introduced unintentionally or if shutdown mechanisms fail to perform as intended. Such conditions challenge the control of reactivity and safe shutdown safety function.

3.4.6 Electrical and Mechanical Energy

Electrical and mechanical energy associated with rotating equipment, power systems, and control mechanisms represent hazard sources that may contribute to accident conditions by causing loss of cooling, loss of shutdown capability, or system transients that challenge fundamental safety functions.

3.5 INTERNAL AND EXTERNAL HAZARD TREATMENT

Following identification of hazard sources in Section 3.4, this section identifies initiating hazards, also referred to as initiating events, that may act upon those hazard sources and initiate accident sequences.

Initiating hazards include both internal failures and external phenomena that can lead to loss of control, release, or mobilization of hazard sources and thereby challenge one or more fundamental safety functions.

Consistent with the analytical conventions defined in Section 1.3, initiating hazards are distinct from hazard sources. Initiating hazards do not themselves constitute sources of energy or radioactive material; rather, they are mechanisms that act upon hazard sources and lead to accident progression.

3.5.1 Internal Initiating Hazards

Internal initiating hazards originate from within the facility and may include:

- failures or malfunctions of systems, structures, or components;
- loss or degradation of electrical power or control functions;

- human actions or errors; and
- internal fires or equipment failures that affect safety-related functions.

Internal initiating hazards may lead to challenges to heat removal, confinement, or reactivity control by disabling systems, degrading barriers, or altering reactor conditions.

3.5.2 External Initiating Hazards

External initiating hazards originate outside the facility boundary and may include site-dependent or regional phenomena that can affect reactor safety functions. Examples include:

- seismic events;
- external fires;
- extreme ambient conditions; and
- other credible natural or man-made external phenomena.

External initiating hazards are evaluated for their potential to affect hazard sources indirectly by degrading structures, systems, or interfaces necessary to maintain fundamental safety functions.

3.5.3 Treatment of Initiating Hazards in Accident Identification

Initiating hazards identified in this section are carried forward to Chapter 4, where they are developed into initiating events, mapped to recognized accident categories consistent with NUREG-1537 Chapter 13, and evaluated for their role in accident scenario development.

Initiating hazards are not screened based on probability. All initiating hazards that could credibly act upon identified hazard sources and challenge fundamental safety functions are considered in the development of accident scenarios and the selection of Safety Basis Events.

3.6 HAZARD REGISTER

Identified hazards are documented in a structured hazard register that provides traceability from hazard sources to initiating events and Safety Basis Events.

The hazard register includes, at a minimum:

- hazard source and description;
- location or system associated with the hazard;
- energy or material involved;
- fundamental safety function(s) potentially challenged; and
- notes on potential initiating mechanisms.

The hazard register is provided in Appendix A and serves as the starting point for initiating-event identification in Section 4.

The hazard register documents hazard sources as defined in Section 3.4 and identifies representative initiating mechanisms that may act upon those hazard sources. Initiating hazards are further developed into initiating events in Chapter 4.

3.7 RELATIONSHIP BETWEEN HAZARDS AND SAFETY FUNCTIONS

Each identified hazard is evaluated with respect to its potential to challenge one or more of the following safety functions:

1. Removal of heat from the reactor

2. Confinement of radioactive material
3. Control of reactivity and safe shutdown

This explicit linkage ensures that hazard identification provides comprehensive coverage of all credible challenges to reactor safety and supports the completeness demonstration required by NUREG-1537 Chapter 13.

3.8 TRANSITION TO INITIATING EVENT IDENTIFICATION

The hazards identified and documented in this chapter form the basis for identifying initiating events in Chapter 4. Each initiating event is derived from one or more hazards and represents a specific mechanism by which a safety function could be challenged.

By systematically identifying hazards prior to initiating-event development, this report ensures that subsequent accident scenario identification is complete, traceable, and defensible.

4 INITIATING EVENT DEVELOPMENT AND ACCIDENT CATEGORIZATION

4.1 PURPOSE OF INITIATING EVENT IDENTIFICATION

The purpose of initiating event identification is to translate the hazard sources identified in Chapter 3, together with the associated initiating hazards, into a comprehensive and traceable set of initiating events that represent credible mechanisms by which the SOLO FOAK could depart from normal operation and challenge one or more fundamental safety functions.

Initiating events represent specific manifestations of internal failures or external phenomena acting upon identified hazard sources and form the starting point for accident scenario development, event screening, grouping, and the identification of Safety Basis Events (SBEs).

Consistent with DOE-HDBK-1224-2024 and the integrated safety analysis principles described in NUREG-1513, initiating events are identified deterministically without consideration of event frequency. Consistent with NUREG-1537, Chapter 13, initiating events are subsequently mapped to recognized accident categories to support systematic accident evaluation.

4.2 INITIATING EVENT IDENTIFICATION METHODOLOGY

Initiating events are identified using a structured, hazards-analysis-driven approach consistent with DOE-HDBK-1224-2024. Each initiating event represents a specific internal failure or external phenomenon acting upon an identified hazard source that could lead to an accident scenario if not mitigated.

The methodology consists of the following steps:

1. **Review each hazard source** identified in the hazard register (Appendix A), together with the associated initiating hazards identified through hazard identification screening.
2. **Identify credible mechanisms** by which each hazard source could be released, mobilized, or become uncontrolled as a result of an initiating hazard.
3. **Define initiating events** in terms of observable, system-level deviations or conditions, rather than individual component failures.
4. **Ensure completeness**, such that the initiating events collectively challenge all three fundamental safety functions defined in Chapter 2.

Initiating events are defined broadly enough to bound variations in specific component-level failures while remaining sufficiently specific to support accident scenario development, event grouping, and traceability to Safety Basis Events.

4.3 TREATMENT OF INTERNAL AND EXTERNAL INITIATORS

Initiating events are classified as internal or external for the purposes of organization, subsequent grouping, and accident categorization.

- **Internal initiating events** originate within the facility and include equipment malfunctions, internal transients, loss of functions, and human-initiated deviations that act upon identified hazard sources.
- **External initiating events** originate outside the facility and may affect multiple systems simultaneously or lead to common-cause challenges to fundamental safety functions by acting upon identified hazard sources.

Both internal and external initiating events are identified and carried forward deterministically, without probabilistic screening, consistent identification expectations of NUREG-1537, Chapter 13.

4.4 INITIATING EVENT CATEGORIES

Based on the hazard sources identified in Chapter 3 and the initiating events derived in Appendix B, initiating events for the SOLO FOAK are grouped into the following initiating event categories. These categories are used solely to organize the initiating event list and do not imply differences in frequency or severity.

4.4.1 Loss or Degradation of Heat Removal

Initiating events in this category involve conditions that reduce or eliminate the ability to remove heat from the reactor, including decay heat following shutdown.

Examples include:

- loss of forced coolant circulation;
- loss of normal heat rejection capability;
- degradation of passive heat removal pathways; and
- loss of supporting systems necessary for heat removal.

These initiating events act upon hazard sources associated with nuclear and decay heat and stored thermal energy, and challenge the removal of heat from the reactor safety function.

4.4.2 Reactivity Control and Shutdown Malfunctions

Initiating events in this category involve deviations in reactivity control or shutdown capability, including conditions that could lead to unintended reactivity insertion or failure to terminate the nuclear chain reaction.

Examples include:

- failure of shutdown mechanisms to actuate as designed;
- spurious withdrawal or malfunction of reactivity control elements; and
- abnormal core conditions leading to reactivity anomalies.

These initiating events act upon hazard sources associated with reactivity and neutron kinetics and challenge the control of reactivity and safe shutdown safety function.

4.4.3 Confinement and Boundary Degradation

Initiating events in this category involve degradation of physical barriers relied upon to confine radioactive material or maintain cooling effectiveness.

Examples include:

- coolant pressure boundary leakage or depressurization;
- confinement structure degradation; and
- internal events leading to bypass or compromise of confinement barriers.

These initiating events act upon hazard sources associated with radioactive material inventory and pressure energy, and challenge the confinement of radioactive material safety function. Depending on event progression, these events may also affect heat removal.

4.4.4 Loss of Electrical Power or Support Functions

Initiating events in this category involve loss or degradation of electrical power or other support functions that indirectly affect reactor safety.

Examples include:

- loss of offsite electrical power;
- loss of onsite power supplies; and
- failure of control, monitoring, or support systems.

These initiating events act upon hazard sources associated with electrical energy and may indirectly challenge one or more fundamental safety functions depending on event progression.

4.4.5 External Event–Initiated Conditions

Initiating events in this category originate from external phenomena that may affect reactor safety functions by acting upon identified hazard sources.

Examples include:

- seismic events;
- external fires;
- extreme ambient conditions; and
- other site-specific external phenomena.

External initiating events are treated as potential common-cause initiators and are carried forward deterministically for accident scenario development.

4.5 INITIATING EVENT LIST

Based on the initiating event categories described above, a master list of initiating events is developed for the SOLO FOAK. Each initiating event is defined in terms of an observable, system-level condition that initiates an accident sequence by acting upon one or more identified hazard sources.

The initiating event master list is provided in Appendix B. For each initiating event, the master list identifies:

- the initiating event identifier;
- a concise initiating event description;
- the hazard source(s) from which the initiating event is derived;
- the fundamental safety function(s) challenged; and
- the applicable initiating event category.

This initiating event master list provides the basis for accident scenario development, event screening and consolidation, and the identification of Safety Basis Events in subsequent chapters.

4.6 MAPPING OF INITIATING EVENTS TO NUREG-1537 CHAPTER 13 ACCIDENT CATEGORIES

Initiating events identified in Chapter 4 and documented in Appendix B are mapped to the accident categories defined in NUREG-1537, Part 1, Chapter 13, to demonstrate comprehensive coverage of all recognized non-power reactor accident classes.

This mapping is organizational in nature and is used to support systematic accident evaluation, selection of limiting events, and identification of the Maximum Hypothetical Accident (MHA). Assignment of an initiating event to an accident category is based on the nature of the initiating event, consistent with NUREG-1537 guidance, and does not imply differences in frequency or severity.

Table 2 - Mapping of Initiating Events to NUREG-1537 Chapter 13 Accident Categories

[[

]]

Initiating events within each accident category are further evaluated in Chapter 5 to develop accident scenarios and are screened and consolidated to identify representative events. Limiting events within each applicable NUREG-1537 accident category are selected in Chapter 6.

5 EVENT SCREENING, CONSOLIDATION, AND SCENARIO DEVELOPMENT

5.1 PURPOSE OF EVENT SCREENING AND SCENARIO DEVELOPMENT

The purpose of this chapter is to develop accident scenarios from the initiating events identified in Chapter 4 and Appendix B, to screen and consolidate similar event sequences, and to identify a set of representative accident scenarios suitable for selection of Safety Basis Events (SBEs).

Event screening and consolidation are performed to ensure that:

- all credible challenges to the fundamental safety functions are addressed;
- initiating events that result in similar accident progressions are grouped in a logical and traceable manner;
- the number of scenarios carried forward for detailed evaluation is minimized without loss of safety significance; and
- the selected scenarios provide a complete and conservative basis for deterministic accident analysis.

This chapter does not evaluate accident consequences, establish acceptance criteria, or select safety-related structures, systems, and components (SSCs). Those activities are addressed in subsequent chapters and in separate licensing documents.

5.2 SCENARIO DEVELOPMENT APPROACH

Accident scenarios are developed by combining each initiating event with the assumed system responses, operator actions, and facility design features that influence accident progression.

For each initiating event, scenario development considers:

- the hazard source(s) acted upon by the initiating event;
- the resulting challenges to fundamental safety functions;
- assumed availability or unavailability of systems consistent with the initiating event definition; and
- credible operator actions consistent with the facility design and operating procedures.

Scenario development is performed deterministically, without consideration of initiating event frequency, consistent with NUREG-1537 Chapter 13.

5.3 SCREENING AND CONSOLIDATION PRINCIPLES

Initiating events and associated accident scenarios are screened and consolidated based on similarity of accident progression, not on probability or consequence magnitude.

Initiating events may be consolidated into a single representative scenario when they:

- act upon the same hazard source(s);
- challenge the same fundamental safety function(s);
- result in similar system-level responses and accident progression; and
- are bounded by a common set of conservative assumptions.

When consolidation is performed, the representative scenario is selected to bound the credible consequences of the individual initiating events being grouped.

Initiating events that lead to distinct accident progressions or challenge different safety functions are retained as separate scenarios.

5.4 RELATIONSHIP TO NUREG-1537 ACCIDENT CATEGORIES

Accident scenarios developed in this chapter are organized and evaluated within the NUREG-1537 Chapter 13 postulated accident categories, as mapped in Section 4.6.

Within each applicable accident category:

- one or more representative scenarios are identified; and
- a limiting event is selected in Chapter 6 to bound the category.

This approach ensures systematic coverage of all required accident categories while avoiding unnecessary duplication of analyses.

5.5 OUTPUT OF CHAPTER 5

The output of this chapter is a consolidated set of **representative accident scenarios** that:

- trace directly to initiating events in Appendix B;
- are mapped to NUREG-1537 postulated accident categories;
- challenge one or more fundamental safety functions; and
- provide the basis for selection of Safety Basis Events in **Chapter 6**.

5.6 REPRESENTATIVE ACCIDENT SCENARIOS BY NUREG-1537 ACCIDENT CATEGORY

This section identifies representative accident scenarios developed from the initiating events listed in Appendix B. Within each category, initiating events that result in similar accident progression and challenges to fundamental safety functions are consolidated into one or more representative scenarios.

The representative scenarios identified in this section are carried forward for selection of limiting events in Chapter 6 and for subsequent deterministic accident analyses.

5.6.1 Insertion of Excess Reactivity

Initiating events mapped to this category include events involving unintended positive reactivity insertion or failure to terminate the nuclear chain reaction, such as inadvertent reactivity insertion and failure of shutdown mechanisms.

The representative accident scenario for this category involves an unintended increase in core reactivity resulting in a power transient, followed by reactor protection system response and transition to a shutdown condition. The scenario challenges the control of reactivity and safe shutdown safety function and establishes bounding conditions for fuel temperature and power excursion analyses.

5.6.2 Loss of Coolant

Initiating events mapped to this category include degradation or failure of coolant pressure boundaries that result in loss of coolant inventory or depressurization.

The representative accident scenario involves a breach of the coolant pressure boundary leading to coolant leakage or loss, degradation of heat removal capability, and potential exposure of radioactive material. The scenario challenges both the confinement of radioactive material and removal of heat from the reactor safety functions.

5.6.3 Loss of Coolant Flow

Initiating events mapped to this category include loss of forced coolant circulation and other conditions that reduce or eliminate coolant flow without immediate loss of coolant inventory.

The representative accident scenario involves loss or degradation of coolant flow leading to reduced heat removal capability, reliance on passive heat transfer mechanisms, and reactor shutdown. The scenario challenges the removal of heat from the reactor safety function and establishes bounding conditions for thermal response following flow degradation.

5.6.4 Mishandling or Malfunction of Fuel

Initiating events mapped to this category include abnormal conditions affecting fuel integrity, including fuel handling errors or fuel-related malfunctions during operation or shutdown states.

The representative accident scenario involves damage to fuel resulting in potential release of radioactive material within the reactor confinement. This scenario challenges the confinement of radioactive material safety function and provides a basis for evaluating bounding radiological release assumptions associated with fuel damage.

5.6.5 Experiment Malfunction

Initiating events mapped to this category include malfunctions or abnormal behavior of experimental facilities or experiment-related equipment that could affect reactor safety.

The representative accident scenario involves an experiment malfunction that introduces a perturbation to reactivity, cooling, or confinement conditions. This scenario challenges one or more fundamental safety functions depending on experiment configuration and is evaluated to ensure that experiment-related events are bounded by the selected limiting events.

If no experiments are credited that could introduce unique accident behavior, this category may be bounded by scenarios identified in other categories.

Note that SOLO MMR is designed for 'island-mode' operation

5.6.6 Loss of Normal Electrical Power

For the SOLO FOAK, which is designed to operate [[

]]

5.6.7 External Events

Initiating events mapped to this category include natural phenomena hazards and external man-made events such as seismic events, external fires, and extreme ambient conditions.

The representative accident scenario involves an external event that challenges multiple systems simultaneously and may result in common-cause failures affecting heat removal, reactivity control, or confinement. External events are treated deterministically and conservatively, and bounding conditions are established for subsequent accident analyses.

5.6.8 Mishandling or Malfunction of Equipment

Initiating events mapped to this category include failures or malfunctions of equipment not otherwise categorized, including internal fires or mechanical failures that affect reactor safety functions.

The representative accident scenario involves equipment malfunction leading to degradation of cooling, control, or confinement functions. These scenarios are evaluated to ensure that they are bounded by the limiting events selected in other applicable categories or retained as distinct limiting events where appropriate.

5.6.9 Summary of Representative Accident Scenarios

The representative accident scenarios identified in this Section provide complete coverage of the NUREG-1537 Chapter 13 postulated accident categories applicable to the SOLO FOAK. These scenarios are used in Chapter 6 to select limiting events within each category and to identify the **Maximum Hypothetical Accident**.

6 SELECTION OF LIMITING EVENTS BY ACCIDENT CATEGORY

6.1 PURPOSE AND APPROACH FOR LIMITING EVENT SELECTION

The purpose of this chapter is to select limiting events within each applicable NUREG-1537 Chapter 13 postulated accident category for the SOLO FOAK. A limiting event is defined as the accident scenario within a given category that is expected to produce the most severe challenge to one or more fundamental safety functions, based on deterministic considerations.

Limiting event selection provides the basis for subsequent detailed accident analyses presented in the PSAR and FSAR and supports identification of the Maximum Hypothetical Accident (MHA).

Limiting events are selected from the representative accident scenarios developed in Chapter 5, which are derived from the initiating events identified in Appendix B and mapped to NUREG-1537 accident categories in Section 4.6.

6.1.1 Deterministic Selection Basis

Limiting events are selected using a deterministic approach, consistent with NUREG-1537 Chapter 13. Selection is based on engineering judgment and conservative assumptions regarding accident progression, without consideration of initiating event frequency or probabilistic risk metrics.

The following factors are considered in determining the limiting event within each accident category:

- the magnitude and duration of the challenge to the applicable fundamental safety function(s);
- the extent of fuel heating or potential fuel damage;
- the potential for degradation of confinement or release of radioactive material; and
- the severity of system or component failures assumed in the accident scenario.

6.1.2 Bounding Considerations

Where multiple accident scenarios are identified within a single accident category, the limiting event is selected to bound the credible consequences of all other scenarios in that category. Bounding is achieved by selecting the scenario that results in the most severe combination of challenges to safety functions under conservative assumptions.

If a single accident scenario bounds multiple NUREG-1537 accident categories, that scenario may be selected as the limiting event for more than one category, provided the bounding basis is clearly documented.

6.1.3 Treatment of Non-Applicable Categories

For accident categories that are not applicable to the SOLO FOAK design or operational envelope, the basis for non-applicability is documented, and no limiting event is selected. Where applicable, such categories may be bounded by limiting events selected in other categories.

6.1.4 Relationship to Maximum Hypothetical Accident Selection

The set of limiting events selected in this chapter provides the basis for identification of the Maximum Hypothetical Accident in Chapter 7. The MHA is selected as the limiting event that produces the greatest potential radiological consequence under conservative assumptions.

6.1.5 Output of Chapter 6

The output of this chapter is a documented set of limiting events, one for each applicable NUREG-1537 accident category, that:

- are traceable to initiating events and representative accident scenarios;
- bound the credible accident space for the SOLO FOAK; and
- form the analytical basis for deterministic accident evaluations in the PSAR and FSAR.

6.2 DEFINITION OF A LIMITING EVENT

The limiting events selected for each applicable NUREG-1537 Chapter 13 postulated accident category for the SOLO FOAK are identified below.

6.2.1 Insertion of Excess Reactivity

The limiting event for this category is an unintended positive reactivity insertion resulting in a rapid increase in reactor power prior to effective shutdown.

This event bounds other reactivity-related scenarios by conservatively assuming the most limiting credible reactivity insertion conditions and response of reactivity control and shutdown systems.

6.2.2 Loss of Coolant

The limiting event for this category is a postulated failure of the primary coolant pressure boundary resulting in the most severe credible loss of coolant inventory.

This event bounds other coolant boundary degradation scenarios by assuming conservative breach characteristics and associated impacts on heat removal and confinement.

6.2.3 Loss of Coolant Flow

The limiting event for this category is a complete loss of forced coolant circulation during reactor operation.

This event bounds other flow degradation scenarios by assuming the most limiting combination of flow reduction and system response, resulting in reliance on shutdown and passive heat removal mechanisms.

6.2.4 Mishandling or Malfunction of Fuel

The limiting event for this category is postulated fuel damage resulting from abnormal fuel handling or operational conditions.

This event bounds other fuel-related scenarios by conservatively assuming the maximum credible extent of fuel damage and associated release of radioactive material within the reactor confinement.

6.2.5 Experiment Malfunction

If experiments are present that could introduce unique accident behavior, the limiting event for this category is the most severe credible experiment-initiated perturbation affecting reactivity, cooling, or confinement.

If no experiments are credited that introduce accident behavior beyond that bounded by other categories, this category is considered bounded by limiting events selected elsewhere.

6.2.6 Loss of Normal Electrical Power

Loss of normal electrical power for the SOLO FOAK includes [[

]

6.2.7 External Events

The limiting event for this category is a bounding external event that results in the most severe credible common-cause challenge to reactor safety functions.

This event bounds other external initiating events by conservatively assuming the external phenomenon that produces the greatest challenge to heat removal, reactivity control, or confinement.

6.2.8 Mishandling or Malfunction of Equipment

The limiting event for this category is a postulated equipment malfunction that results in the most severe degradation of reactor safety functions not otherwise bounded by other categories.

Where equipment malfunctions are bounded by limiting events selected in other categories, this category is considered bounded accordingly.

6.2.9 Summary

The limiting events identified in Section 6.2 establish the complete set of bounding accident scenarios for the SOLO FOAK and are carried forward for identification of the Maximum Hypothetical Accident in Chapter 7.

7 MAXIMUM HYPOTHETICAL ACCIDENT DEFINITION BASIS

7.1 PURPOSE AND BASIS OF THE MAXIMUM HYPOTHETICAL ACCIDENT

The purpose of this chapter is to identify the Maximum Hypothetical Accident (MHA) for the SOLO FOAK. The MHA serves as a bounding construct for evaluation of radiological consequences and establishes conservative assumptions regarding fuel damage and radioactive material release.

The MHA is distinct from the set of Safety Basis Events (SBEs) identified in Chapter 6. SBEs represent credible accident scenarios that are evaluated deterministically against defined acceptance criteria or surrogate figures of merit (FOMs), such as fuel temperature limits or fuel failure criteria, to demonstrate adequate system performance.

In contrast, the MHA assumes conservative and bounding damage mechanisms or release fractions that may exceed those calculated for the analyzed SBEs. The purpose of the MHA is not to demonstrate system performance under realistic conditions, but rather to establish an upper bound on potential radiological consequences.

7.1.1 Deterministic and Bounding Basis

Selection of the MHA is performed using a deterministic approach consistent with NUREG-1537 Chapter 13. The MHA is selected from among the limiting events identified in Section 6.2 and is defined using conservative assumptions regarding:

- the extent of fuel damage or failure;
- the quantity and form of radioactive material available for release;
- degradation of confinement barriers; and
- transport pathways that could contribute to offsite exposure.

The assumptions used in defining the MHA are intentionally more severe than the expected outcomes of the deterministic safety analyses performed for the SBEs.

7.1.2 Relationship to Safety Basis Event Analyses

The deterministic safety analyses performed for the SBEs evaluate accident progression using defined acceptance criteria or surrogate figures of merit that demonstrate:

- maintenance of fuel integrity or limits on fuel damage;
- acceptable peak fuel temperature;
- preservation of confinement performance; and
- overall protection of public health and safety.

As long as the conservative assumptions embedded in the MHA (e.g., assumed fuel failure or release fraction) exceed the damage or release predicted by the SBE analyses, the safety case benefits from an additional layer of **defense-in-depth**. This layered approach ensures that even if SBE performance margins are approached, bounding radiological consequences remain within acceptable limits.

7.1.3 Scope of This Chapter

This chapter identifies the MHA and establishes the basis for its bounding assumptions. Detailed accident consequence calculations and comparison to regulatory dose criteria are presented in the PSAR and FSAR, consistent with NUREG-1537 Chapter 13.

7.2 IDENTIFICATION OF THE MAXIMUM HYPOTHETICAL ACCIDENT

For the SOLO FOAK, the Maximum Hypothetical Accident (MHA) is defined as [[

]]

7.2.1 Basis for Selection

The selected MHA bounds the radiological consequences of the limiting events identified in Chapter 6. Deterministic analyses of the Safety Basis Events are expected to demonstrate compliance with defined acceptance criteria, such as peak fuel temperature limits or fuel failure thresholds. In contrast, the MHA assumes a damage state that exceeds those predicted outcomes.

The MHA construct therefore envelopes:

- all analyzed Safety Basis Events;
- potential uncertainties in fuel performance modeling;
- conservative assumptions regarding radionuclide release and transport; and
- degradation of confinement performance consistent with a severe hypothetical condition.

7.2.2 Conservatism and Defense-in-Depth

The assumption of immediate failure of one complete fuel assembly represents a bounding and intentionally conservative condition. This assumption:

- exceeds the expected damage predicted by deterministic safety analyses;
- provides a clear upper bound on available radioactive inventory for release; and
- establishes a defensible margin between analyzed system performance and bounding radiological consequences.

This layered approach reinforces the defense-in-depth philosophy underlying the SOLO safety case.

8 FINAL SAFETY BASIS EVENT SET AND CONCLUSIONS

8.1 PURPOSE OF THIS CHAPTER

This chapter summarizes the final set of Safety Basis Events (SBEs) identified for the SOLO FOAK and documents the conclusions of the hazards analysis and initiating event identification process.

The SBEs identified in this report establish the deterministic accident set for detailed analysis in the PSAR and FSAR and provide the foundation for SSC safety classification and evaluation of system performance.

8.2 SUMMARY OF METHODOLOGY

Hazard identification and accident development for the SOLO FOAK were performed using a structured, deterministic approach consistent with:

- DOE-HDBK-1224-2024 and DOE-HDBK-1163-2020 (methodological guidance), and
- NUREG-1537, Chapter 13 (regulatory expectations for non-power reactors).

The methodology included:

1. Identification of hazard sources associated with radioactive material and stored energy (Chapter 3 and Appendix A);
2. Identification of initiating events that could act upon those hazard sources (Chapter 4 and Appendix B);
3. Development and consolidation of representative accident scenarios (Chapter 5);
4. Selection of limiting events within each applicable NUREG-1537 postulated accident category (Chapter 6); and
5. Identification of a bounding Maximum Hypothetical Accident (Chapter 7).

This structured approach ensures completeness, traceability, and alignment with NRC licensing expectations.

8.3 FINAL SAFETY BASIS EVENT SET

The final Safety Basis Event set for the SOLO FOAK consists of the limiting events identified in Section 6.2, organized by the NUREG-1537 Chapter 13 postulated accident categories:

- Insertion of excess reactivity;
- Loss of coolant;
- Loss of coolant flow;
- Mishandling or malfunction of fuel;
- Experiment malfunction (as applicable or bounded);
- Loss of normal electrical power;
- External events; and
- Mishandling or malfunction of equipment.

Within each applicable category, one limiting event has been selected to bound credible accident progression and challenges to the fundamental safety functions:

1. Removal of heat from the reactor;

2. Confinement of radioactive material; and
3. Control of reactivity and safe shutdown.

These limiting events collectively define the deterministic Safety Basis Event envelope for the SOLO FOAK.

8.4 RELATIONSHIP BETWEEN SBES AND THE MAXIMUM HYPOTHETICAL ACCIDENT

The Safety Basis Events are evaluated deterministically against defined acceptance criteria or surrogate figures of merit, such as fuel temperature limits or fuel failure thresholds, to demonstrate system performance under credible accident conditions.

The Maximum Hypothetical Accident (MHA), as defined in Chapter 7, is a separate bounding construct used for conservative radiological consequence evaluation. The MHA assumes [[

]]

Provided that:

- SBE analyses demonstrate compliance with defined performance criteria; and
- radiological consequences calculated for the MHA remain within applicable regulatory limits;
- the SOLO safety case incorporates clear layers of defense-in-depth.

8.5 COMPLETENESS OF THE ACCIDENT SET

The combination of:

- systematic hazard source identification,
- comprehensive initiating event development,
- mapping to all applicable NUREG-1537 postulated accident categories, and
- selection of limiting events within each category,

demonstrates that the full spectrum of credible accident conditions for the SOLO FOAK has been addressed.

No credible internal or external event that could challenge the fundamental safety functions has been excluded without technical basis.

8.6 INTERFACE WITH SUBSEQUENT LICENSING ANALYSES

The outputs of this Topical Report support subsequent licensing activities as follows:

- **PSAR/FSAR Chapter 13 (Accident Analyses):**
Detailed deterministic analyses of the selected Safety Basis Events and the Maximum Hypothetical Accident.
- **SSC Safety Classification Topical Report:**
Identification of structures, systems, and components required to perform safety functions under the selected SBES.
- **Emergency Planning and Siting Evaluations:**
Use of MHA consequence results to confirm adequate protection of public health and safety.

This report therefore provides the front-end analytical foundation for the SOLO FOAK safety case.

8.7 CONCLUSIONS

The hazards analysis and identification of Safety Basis Events for the SOLO FOAK have been performed using a structured, deterministic methodology consistent with NRC regulatory guidance.

The resulting SBE set:

- fully addresses the NUREG-1537 Chapter 13 postulated accident categories;
- challenges all three fundamental safety functions;
- provides a clear and traceable basis for deterministic safety analysis; and
- supports a conservative and defense-in-depth-oriented Maximum Hypothetical Accident construct.

Accordingly, the accident set defined in this report provides a complete and technically defensible basis for detailed safety evaluation of the SOLO FOAK.

9 REFERENCES

- [1] "US Nuclear Regulatory Commission, Guidelines for Preparing and Reviewing Applications for Licensing of Non-Power Reactors, NUREG-1537, Part 1 and Part 2".
- [2] DOE-HDBK-1163-2020, "DOE HANDBOOK: INTEGRATION OF HAZARD ANALYSES," October 2020.
- [3] DOE-HDBK-1224-2024, "DOE HANDBOOK HAZARD AND ACCIDENT ANALYSIS," February 2024.
- [4] "US Nuclear Regulatory Commission, Guidance for Developing Principal Design Criteria for Non-Light Water Reactors, RG 1.232, Revision 0".

APPENDIX A - HAZARD IDENTIFICATION, SCREENING, AND HAZARD REGISTER

A.1 PURPOSE AND ROLE OF APPENDIX A

This appendix documents the hazard identification process for the SOLO FOAK and presents the resulting hazard register. Consistent with the analytical conventions defined in Section 1.3, hazards are treated as sources of energy or radioactive material, while internal failures and external phenomena are treated as initiating hazards that act upon those hazard sources.

Hazard identification is performed using a structured, systematic screening process consistent with the methodology illustrated in DOE-HDBK-1224-2024, including the checklist-based approach exemplified by Table 2-1 of that handbook. The purpose of this appendix is to:

- demonstrate that all relevant classes of hazardous energy and material have been systematically considered;
- identify the specific hazard sources applicable to the SOLO FOAK;
- establish the association between hazard sources and credible initiating hazards; and
- provide the foundation for initiating event identification and accident scenario development.

This appendix does not identify accident scenarios or Safety Basis Events; those are developed in Chapters 4 through 6.

A.2 HAZARD IDENTIFICATION SCREENING APPROACH

Hazard identification for the SOLO FOAK is performed in three sequential steps:

1. **Hazard source identification** – identification of sources of energy or radioactive material internal to the facility that could challenge fundamental safety functions if uncontrolled;
2. **Initiating hazard applicability screening** – identification of internal failures and external phenomena that could credibly act upon each hazard source; and
3. **Hazard register development** – documentation of hazard sources and their relationship to safety functions and initiating hazards.

This structure preserves the intent of DOE-HDBK-1224-2024 while presenting the results in a form compatible with NUREG-1537 Chapter 13.

A.3 HAZARD SOURCE IDENTIFICATION (ENERGY AND MATERIAL AT RISK)

A.3.1 Purpose

This step identifies **hazard sources only**, defined as sources of energy or radioactive material that exist independent of accident initiators. Initiating hazards such as fires, seismic events, or loss of power are explicitly excluded from this step.

A.3.2 Hazard Source Identification Table

Table 3 - Hazard Source Identification

[[

]]

A.4 INITIATING HAZARD APPLICABILITY SCREENING

A.4.1 Purpose

This step identifies initiating hazards—internal failures and external phenomena—that could credibly act upon the identified hazard sources and lead to loss of control, release, or mobilization of energy or radioactive material.

Initiating hazards are not alternatives to hazard sources; rather, they are paired with hazard sources to form accident initiators.

A.4.2 Initiating Hazard to Hazard Source Association

Table 4 - Initiating Hazard Applicability to Hazard Sources

[[

]]

This table explicitly establishes the association between hazard sources and initiating hazards, resolving the ambiguity identified in the screening step.

A.5 HAZARD REGISTER

A.5.1 Purpose

The hazard register consolidates the results of hazard source identification and initiating hazard screening into a traceable form that links hazard sources to fundamental safety functions and to representative initiating hazards.

A.5.2 Hazard Register Table

Table 5 - SOLO FOAK Hazard Register

[[

]]

A.6 RELATIONSHIP TO INITIATING EVENT IDENTIFICATION

The initiating hazards identified in Tables A-2 and A-3 are developed into specific initiating events in Chapter 4, where they are categorized and mapped to recognized accident categories consistent with NUREG-1537 Chapter 13. No initiating hazard is screened out based on probability at this stage.

A.7 SUMMARY AND COMPLETENESS STATEMENT

Appendix A demonstrates a complete and systematic hazard identification process consistent with DOE-HDBK-1224-2024 and DOE-HDBK-1163-2020, while remaining fully compatible with NRC expectations for deterministic accident analysis. The process explicitly establishes the chain:

Hazard source → Initiating hazard → Initiating event → Accident scenario → Safety Basis Event

All hazard sources capable of challenging fundamental safety functions have been identified, and all credible initiating hazards capable of acting upon those hazard sources are carried forward for accident analysis.

APPENDIX B - INITIATING EVENT IDENTIFICATION AND MASTER LIST

B.1 PURPOSE AND SCOPE

This appendix documents the identification and traceability of initiating events for the SOLO FOAK. Initiating events represent specific internal failures or external phenomena that, by acting upon identified hazard sources, may initiate accident sequences that challenge one or more fundamental safety functions.

Consistent with the definitions established in Section 1.3, initiating events are distinct from hazard sources. Hazard sources represent sources of energy or radioactive material, while initiating events are the mechanisms by which those hazard sources may be released, mobilized, or become uncontrolled.

The purposes of this appendix are to:

- document a comprehensive and systematic list of initiating events;
- demonstrate traceability from hazard sources (Appendix A) to accident scenario development;
- support mapping of initiating events to the NUREG-1537 Chapter 13 postulated accident categories; and
- provide the basis for accident scenario development, event screening and consolidation, and Safety Basis Event (SBE) selection in subsequent chapters.

Initiating events are identified deterministically. No initiating event is screened out based on probability.

B.2 INITIATING EVENT IDENTIFICATION PROCESS

Initiating events are identified using a structured, hazards-analysis-driven approach consistent with DOE-HDBK-1224-2024, tailored for NRC licensing of non-power reactors under 10 CFR Part 50 and consistent with NUREG-1537 Chapter 13.

The identification process includes:

1. review of hazard sources identified in Appendix A, together with associated initiating hazards;
2. identification of credible internal failures or external phenomena that may act upon each hazard source;
3. definition of initiating events at the system level, rather than at the level of individual component failures; and
4. verification that the set of initiating events collectively challenges all three fundamental safety functions defined in Chapter 2.

Initiating events are defined broadly enough to bound variations in component-level failures while remaining sufficiently specific to support accident scenario development and grouping.

B.2 INITIATING EVENT MASTER LIST

Initiating events are defined at the **system or functional level**, rather than at the level of individual component failures. This approach ensures that initiating events:

Table 6 - SOLO FOAK Initiating Event Master List

[[

]]

Mapping of each initiating event to the applicable NUREG-1537 Chapter 13 postulated accident category is provided in Section 4.6.

B.4 RELATIONSHIP TO ACCIDENT SCENARIO DEVELOPMENT

Each initiating event identified in Table B-1 is evaluated in Chapter 5 to develop accident scenarios by combining the initiating event with applicable hazard sources, system responses, and assumed operator actions. Initiating events that lead to similar challenges to fundamental safety functions may be consolidated into representative accident scenarios.

B.5 RELATIONSHIP TO SAFETY BASIS EVENT SELECTION

Initiating events serve as the starting point for accident sequence development and the selection of Safety Basis Events (SBEs) in Chapter 6. SBEs are selected to bound the consequences of initiating events within each applicable NUREG-1537 Chapter 13 postulated accident category, as documented in Section 4.6.

B.6 COMPLETENESS AND CONSISTENCY STATEMENT

The initiating events documented in this appendix represent all credible internal and external events identified through the systematic hazard identification and screening process described in Appendix A. Together, Appendices A and B provide a complete and traceable basis for accident scenario development consistent with DOE-HDBK-1224-2024, DOE-HDBK-1163-2020, and NUREG-1537 Chapter 13.