Deep Fission Gravity Reactor

Nuclear Safety Design Agreement (NSDA)

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PUBLIC VERSION

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This public version is based on RPP-LIC-NSDA, Revision 0, issued July 17, 2026, and approved by the U.S. Department of Energy in letter CLN260841 dated July 14, 2026.

Confidential Treatment Request Under FOIA Exemption 4

Deep Fission, Inc. ("**Deep Fission**" or "**DFI**") respectfully requests, pursuant to 10 CFR 1004.11 and Exemption 4 of the Freedom of Information Act (5 U.S.C. § 552(b)(4)), that the Department of Energy withhold from public disclosure any information contained herein that is marked "Proprietary," "Confidential," or "Commercially Sensitive."

The enclosed information consists of technical, commercial, and financial data that was developed at private expense and is not publicly available. Release of this information would likely cause substantial competitive harm to DFI by disclosing proprietary design methods, business strategies, or cost structures to competitors.

DFI requests that DOE: (i) provide prompt written notice of any FOIA request seeking disclosure of the enclosed information, and (ii) allow DFI a reasonable opportunity to substantiate its objections before DOE determines whether to release any portion of the information, consistent with DOE's FOIA procedures and the requirements of 10 CFR 1004.11.

REVISION HISTORY

Rev.	Date	Affected Section(s)	Description
A	12/12/2025	All	Initial Issue of Document
B	4/29/2026	All	Updates content to align with the full power, commercial-ready solution and timeline. Incorporates Deep Fission's responses to DOE comments to Revision A as described in Deep Fission document RPP-LIC-RPT-001, "DOE Comments and Deep Fission Responses on NSDA Revision A."
C	6/25/2026	See Description	Changes to Address DOE Feedback: 2.1.2 Performance Objectives: Changed power rating from 25 MW_t to 19.5 MW_t. 3.2 Safety Analysis Process: Added 10 CFR Part 830.203, "Unresolved safety question process," and DOE G 424.1-1C, "Implementation Guide for Use in Addressing Unreviewed Safety Question Requirements." Figure 4: Regulatory Engagement Process Flow and Swim Lanes: Updated operations flow to show fuel arriving after readiness review and authorization to startup. 9 Dose Consequence: Added values for power and effective full power days. 10 Natural Phenomena Hazard Design Categorization: Provided the MHA details that support the NDC categorization. New Section 13 Fire Hazards Analysis and Fire Protection Program. New Section 14 Principal Design Criteria. New Appendix B Safety Basis Strategy. Changes to Provide Clarity: 2.1.2 Performance Objectives: focus on full-scale reactor system 2.2.1.3 Primary Coolant Control: added shut down language 2.2.1.4 Aqueous Reactivity Control and Shutdown: updated description to clarify functionality

Rev.	Date	Affected Section(s)	Description
			2.2.1.6 Borehole Structure: updated description to clarify functionality 2.2.1.7 Borehole Closure: updated description to clarify functionality 2.2.1.8 Borehole Water Control: updated description to clarify functionality 2.2.1.10 Radioactive Waste: updated description to clarify functionality 2.3.5 Reactor Startup: rephrased 'withdrawing negative reactivity' for clarity 2.3.6 Reactor Critical: added footnote to define reactor period Table 2: Safety Analysis Process Description: updated description to clarify functionality 6.3 Reactivity Control for Shutdown: updated description to clarify functionality 6.6 System Response to Off-Normal Operations: updated description to clarify off-normal operations to be analyzed 9. Dose Consequence: updated description to clarify analysis. Other changes: Minor grammatical corrections throughout. Footer: Correct copyright date.

0	7/17/2026	General	Approved NSDA, incorporates:
			• Redline edits from NSDA Rev C.
			• DOE Conditions of Approval enclosed in DOE letter CLN260841, Approval of Deep Fission Gravity Reactor, dated July 14, 2026.
			  o Section 9 Dose Consequence, paragraph 2: corrected maximum rated power to 19.5 MWt
			  o General: removed all references to 10 CFR 57 and corresponding NUREG-2271

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Acronyms

Acronym	Definition
AOO	anticipated operational occurrence
ARCS	aqueous reactivity control and shutdown
ASME	American Society of Mechanical Engineers
AST	alternative source term
ATO	authority to operate
BC	borehole closure
BWC	borehole water control
CEO	Chief Executive Officer
CFR	*Code of Federal Regulations*
CM	configuration management
CNO	Chief Nuclear Officer
COO	Chief Operating Officer
COR	Code of Record
DBA	design basis accident
DBE	design basis event
D&D	decontamination and decommissioning
DOE	U.S. Department of Energy
DSA	documented safety analysis
EG	evaluation guideline
FMEA	failure modes and effects analysis
FSAR	final safety analysis report
GDC	General Design Criteria
GOCO	Government-Owned, Contractor-Operated
GOGO	Government-Owned, Government-Operated
HAZOP	hazard and operability study
HS&Q	health, safety, and quality
I&C	instrumentation and control
INP	inherent or natural passive
JTG	Joint Test Group
LCO	limiting conditions for operations
LEU	low-enriched uranium
LOCA	loss-of-coolant accident
L-RASCI	liaison / responsible / accountable / supportive / consulted / informed (role matrix)
LWR	light-water reactor
MC	module control
MHA	maximum hypothetical accident
NDC	natural phenomena hazard design category
NE	Nuclear Energy
NEPA	National Environmental Policy Act
NPH	natural phenomena hazard
NRC	U.S. Nuclear Regulatory Commission
NSDA	nuclear safety design agreement

Acronym	Definition
OTA	Other Transaction Agreement
PCC	primary coolant control
PDC	principal design criteria
PDSA	preliminary documented safety analysis
PHX	primary heat exchanger
PP	primary piping
PRA	probabilistic risk assessment
PSAR	preliminary safety analysis report
PSD-1	ASME Plant Systems Design Standard
PWR	pressurized water reactor
QAP	quality assurance program
QAPD	quality assurance program description
RG	regulatory guide
RI	reactor and internals
RISC	risk-informed safety-class
RM	requirements management
RPP	Reactor Pilot Project
RR	readiness review
SAFDL	specified acceptable fuel design limits
SBAA	Safety Basis Approval Authority
SBS	Safety Basis Strategy
SER	safety evaluation report
SLT	state, local, and tribal (stakeholders)
SMR	small modular reactor
SP	secondary piping
SRP	standard review plan
SSC	structures, systems, and components
TEDE	total effective dose equivalent
TS	technical specifications
TSR	technical safety requirements
VIT	vacuum-insulated tubing

Executive Summary

Deep Fission and the U.S. Department of Energy (DOE) establish in this nuclear safety design agreement (NSDA) a shared and early alignment on the nuclear safety expectations governing the Reactor Pilot Project (RPP). This NSDA summarizes the design, safety functions, regulatory engagement processes, and key decisions that ensure the safe construction, installation, and operation of the reactor in a deep geological environment. The pilot uses a first-of-a-kind Deep Fission Gravity Nuclear Reactor ("Gravity Reactor") configuration: a compact, passive primary loop, light-water reactor (LWR) deployed underground in a water-filled deep borehole. This configuration uses natural hydrostatic pressure, geological isolation, and passive thermal-hydraulic mechanisms to provide multiple, redundant layers of safety that reduce or eliminate the accident conditions typically associated with surface-based reactors.

The design features – including deep borehole siting, passive coolant pressurization via a hydrostatic water column, compact reactor and primary loop design, natural circulation cooling, and use of qualified commercial pressurized water reactor (PWR) fuel – provide substantial safety advantages. The subsurface environment inherently stabilizes coolant pressure, prevents rapid depressurization, and supplies a large passive heat sink. Natural circulation eliminates the need for pumps and reduces failure modes, while strong negative fuel and moderator temperature coefficients supply a self-regulating shutdown response to off-normal conditions. The design adopts modular components, vacuum-insulated concentric piping, and passive reliance on downhole geology to confine radioactivity and maintain structural integrity. These features collectively enable a conservative and inherently stable safety posture.

Historically, regulators established existing requirements for large, surface-based LWRs to address vulnerabilities to loss-of-coolant accidents (LOCA). As a result, they imposed deterministic and highly prescriptive rules to protect the reactor coolant pressure boundary. For the RPP, blanket compliance with such existing regulatory requirements may impose undue costs and burdens without commensurate safety benefits. As such, Deep Fission does not claim to conform to all preexisting LWR regulatory guidance. Rather, this document demonstrates how Deep Fission intends to meet the outcome objectives of regulations to satisfy fundamental safety functions, consistent with a performance-based approach to DOE authorization and, ultimately, U.S. Nuclear Regulatory Commission (NRC) review and approval.

This NSDA defines the safety analysis approach and ensures it satisfies Title 10 *Code of Federal Regulations* (10 CFR) Part 830, "Nuclear Safety Management," while also incorporating the analytical rigor of 10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities," to support long-term commercialization. The analytic toolset used by Deep Fission leverages decades of PWR operating experience, proven methodologies, and pre-approved "safe harbor" regulatory guidance. Scoping analysis shows that the reactor's passive features, subsurface siting, and small fission product inventory sharply constrain potential radiological release pathways.

The dose consequence evaluation of a credible maximum hypothetical accident (MHA) demonstrates extremely low offsite and worker dose. Under conservative assumptions, the estimated co-located worker dose remains below 5 rem total effective dose equivalent (TEDE) (i.e., less than DOE's 5–25 rem range to challenge the evaluation guidelines [EG]). Even in an

extreme, physically implausible accident scenario, the radiological consequences remain low. Deep Fission anticipates that safety structures, systems, and components (SSCs) will fall below Natural Phenomena Hazard Design Category 1 (NDC-1, see NE-STD-1020-2025, “Natural Phenomena Hazards Analysis and Design Criteria for DOE Facilities”), supporting a graded approach that reflects the reactor’s low hazard potential and substantial passive protections.

Key safety decisions described in this document anchor Deep Fission’s design and regulatory strategy. These include, but are not limited to:

- Adopting a safety philosophy centered on inherent and passive safety
- Selecting qualified commercial PWR fuel
- Implementing reliable reactivity control mechanisms
- Limiting the generated radiological source term
- Relying on natural coolant circulation
- Embedding the reactor within a deep geologic environment to attenuate radiation
- Utilizing a compact design that minimizes piping and potential leak points
- Covering the reactor with a substantial column of water that provides inherent pressure safety, cooling, and radionuclide scrubbing.

With an outcome-based focus on protection of the public and workers, Deep Fission deterministically evaluates transients and accidents and supports its analyses with risk information where appropriate.

Through this NSDA, Deep Fission and DOE establish a clear, predictable regulatory engagement model that integrates safety early, aligns expectations, and enables efficient progression toward design maturity, safety basis approval, readiness review, and operations. This agreement enables Deep Fission to demonstrate the feasibility of deep borehole PWR deployment while upholding DOE’s standards for nuclear safety and security, operational discipline, and public protection.

1 Introduction

This Nuclear Safety Design Agreement (NSDA) establishes early formal alignment between the Department of Energy (DOE) Office of Nuclear Energy (NE) and Deep Fission regarding the nuclear safety basis expectations for the project. Its purpose is to ensure both parties share a common understanding of the applicable design requirements, the planned safety analysis approach, the regulatory engagement process, and the key safety-related decisions that will guide the development, implementation, and operation of the pilot. Achieving this alignment early in the design process is essential to prevent misinterpretation of regulatory expectations, avoiding costly redesign, and supporting an efficient and predictable path toward DOE authorization.

(**NOTE:** *For consistency and ease of understanding, this document uses present tense to describe capabilities and processes. However, when referring to project events or milestones that already have taken place or that are scheduled to occur, the narrative shifts to past or future tense to maintain clarity and accuracy*)

2 Project Purpose and Design

2.1 Purpose

This project aims to demonstrate the feasibility of constructing, installing, and operating a small modular reactor (SMR) – i.e., Deep Fission's Gravity Nuclear Reactor ("Gravity Reactor") – at power underground in a water-filled deep borehole. Deep Fission seeks to validate criticality achievement and power operations, system functionality, and safety protocols before future (i.e., beyond this initial pilot) commercial-scale deployment stages.

2.1.1 Functional Objectives

This project will achieve reactor criticality and power operation at depth inside a water-filled borehole. Deep Fission will demonstrate safe assembly, installation, and lowering of the Gravity Reactor, piping, and associated heat exchange systems into a large-diameter borehole. The team will confirm reactivity control and shutdown capabilities, and collect instrumentation data on neutron flux, temperature, and pressure for analytical validation.

2.1.2 Performance Objectives

The Gravity Reactor will initially operate at zero-power criticality for a short period of time prior to moving to demonstration of power operations up to 19.5 MW_t. The project will validate analytical models of the full-scale reactor system.

2.1.3 Safety Objectives

The project will maintain reactor subcriticality during handling, installation, and post-test phases. The radioactive source term will remain low. Passive confinement, inherent pressure safety, inherent cooling, and engineered features will form the foundation for safe operation and regulatory confidence. Deep Fission will minimize the potential for release of radioactive materials, protect the health and safety of the public and workers, and ensure compliance with DOE authorization requirements and their outcome objectives.

(**NOTE:** *Though they may help reach safety objectives, engineered safety features and other structures, systems, and components [SSCs] should not be presumed to be safety-related. Safety classification will be determined upon completion of the safety analysis process.*)

2.2 Design Summary

The RPP leverages proven nuclear and drilling technologies to demonstrate the feasibility of subsurface nuclear power generation. The design adapts the light-water pressurized water reactor (PWR) model for a deep geological environment, using proven deep borehole drilling and casing techniques.

The plant consists of subsurface and surface systems.

- Subsurface: borehole casing, reactor canister, primary system, a portion of the secondary system
- Surface: control systems, borehole closure system (i.e., wellhead), secondary heat exchanger and tertiary coolant system, power conversion, and support facilities

An overhead rig system similar to what is used in the commercial drilling industry lowers and raises the reactor to and from depth.

2.2.1 System Overview

Figure 1 identifies a key subset of the RPP systems.

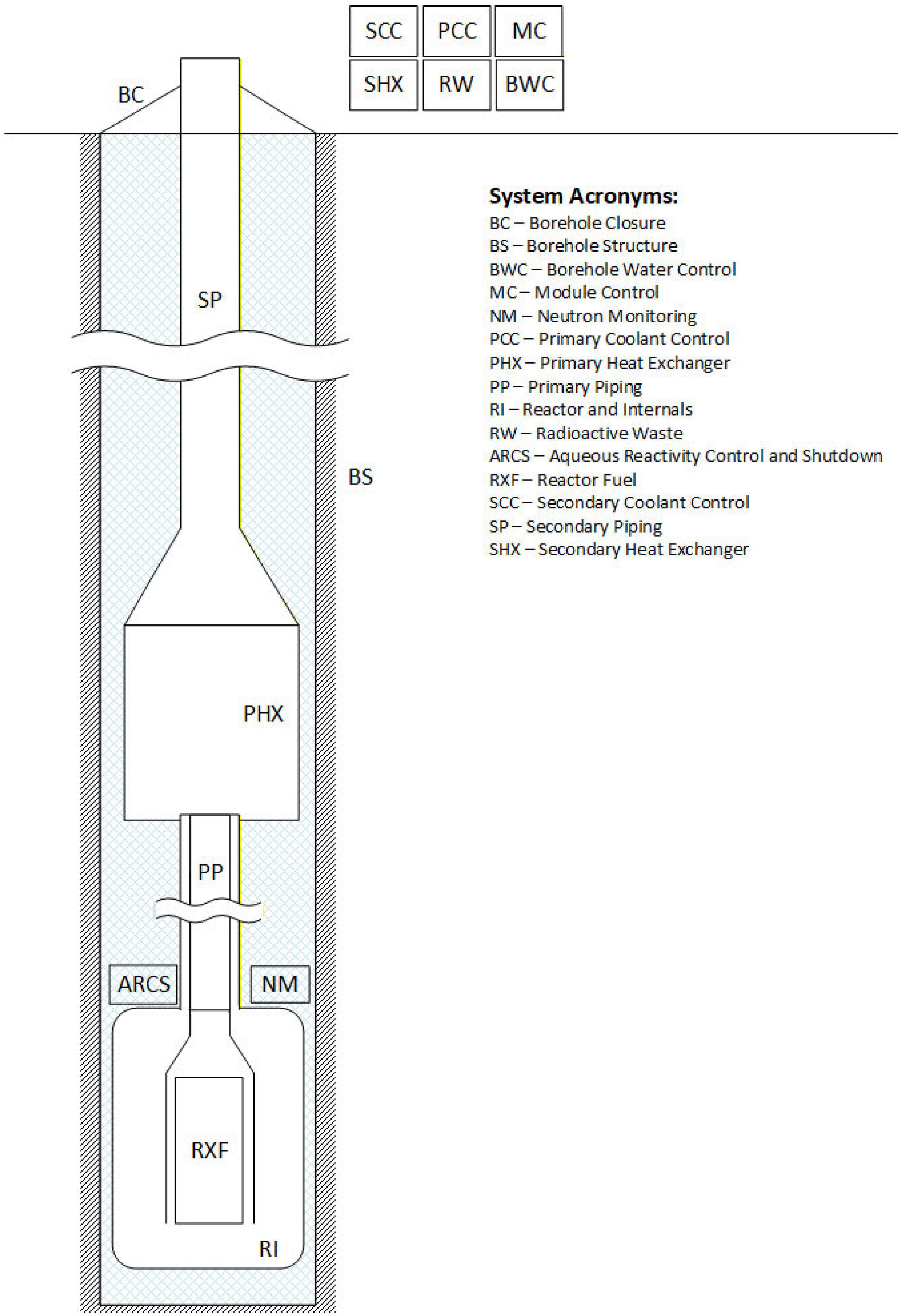

Figure 1: Key Subset of RPP Systems

2.2.1.1 Reactor and Internals

The reactor and internals (RI) assembly houses the Gravity Reactor fuel and structural components that sustain stable operations under high-pressure conditions. The reactor core resides within a sealed canister. The pressure inside the canister approximates the pressure outside the canister, as water columns to the surface create both pressures. The RI assembly uses conventional low-enriched uranium (LEU) fuel assemblies in a compact PWR configuration. Integrated coolant channels promote natural convection, enabling the reactor to remove heat without primary coolant pumps.

The canister fits within a large-diameter borehole while accommodating the necessary fuel assemblies, sensors, and coolant pathways. With a very short operating life, no moving parts, and passive safety features, the system enhances reliability and reduces the need for maintenance. Once installed, operators monitor the reactor via sensors that provide input to the module control (MC) system.

2.2.1.2 Primary Piping and Primary Heat Exchanger

The primary piping (PP) system forms a closed circuit for circulation of coolant between the reactor core and the primary heat exchanger (PHX). The PP system uses concentric pipes to transfer primary coolant. When the core generates heat, hot water naturally rises through the inner pipe from the core to the PHX, where it transfers heat to the secondary coolant. Cooled primary water then flows downward through the outer pipe annulus to re-enter the core.

The PP system operates entirely by natural circulation, eliminating the need for mechanical pumps and reducing potential failure points. The vertical height difference between the core and the PHX provides the buoyant force needed for stable flow. The PP materials resist corrosion, cracking, and degradation, maintaining performance and safety over the system's lifetime.

2.2.1.3 Primary Coolant Control

The primary coolant control (PCC) system manages the reactor's internal coolant conditions (e.g., volume, pressure, temperature, water chemistry) from the surface. Operators use it to control reactivity, maintain coolant chemistry during operation, and shut down when desired. The PCC connects to the primary loop through small-diameter lines that extend from the surface to the reactor depth.

The PCC system includes pumps, sensors, isolation valves, and instrumentation to detect anomalies and respond automatically to protect the reactor. Operators adjust reactivity as needed by changing the concentration of boron in the reactor coolant volume. During startup, operators use the PCC to control boron dilution to safely reach criticality. The PCC automatically increases boron concentration on high neutron flux to initiate reactor shutdown and ensure subcriticality.

2.2.1.4 Aqueous Reactivity Control and Shutdown

The aqueous reactivity control and shutdown (ARCS) system is a Gravity Reactor feature that provides additional assurance that any transient resulting in an insertion of positive reactivity to the core terminates quickly, shutting down the core and maintaining it in a subcritical state. The ARCS system is independent and provides core reactivity control redundant to the control provided by the PCC system under normal operating conditions. This control is further supported by the presence of a soluble neutron absorber in the borehole water and the inherent negative reactivity feedback of the core under transient conditions. Transient analyses demonstrate that the Gravity Reactor core cannot reach melting temperatures, which ensures that postulated releases of the available source term remain within acceptable dose consequences. Therefore, the ARCS system is not required to mitigate the effects of postulated transients, rather it provides additional defense-in-depth.

The ARCS system consists of a pressurized reservoir in proximity and connected to the reactor canister using redundant steel tubing and valving capable of automatic and manual actuation. The reservoir contains an aqueous solution of soluble neutron absorber in a concentration high enough to rapidly shut down the reactor when mixed with the full primary coolant system volume. Using connected steel tubing from the surface, the ARCS system reservoir is filled (i.e., charged and pressurized) and remains in standby to be actuated when needed.

This design enables the system to provide automatic and on-demand pressurized injection of negative reactivity into the Gravity Reactor core via a high concentration of water-soluble absorbers (e.g., boron). This injection at a high flowrate into the downcomer region of the reactor canister rapidly introduces and mixes the absorber, shuts down the reactor, and brings it into a maintained subcritical state. Following initial actuation, the ARCS system refills the reservoir from the surface, resets, and becomes available for repeat actuation.

This system operates on similar principles to the proven and widely deployed standby liquid control system implemented for conventional boiling water reactors.

2.2.1.5 Secondary Piping

The secondary piping (SP) system removes heat from the PHX and transfers it to the surface. The SP system has a concentric pipe, vacuum-insulated tubing (VIT) design similar to the primary loop. Heated secondary coolant rises through the inner pipe while cooled water returns to the PHX through the outer annulus. At the surface, the SP system includes pumps, valves, and instrumentation that measure temperature, pressure, and flow rate.

2.2.1.6 Borehole Structure

The borehole structure forms the primary physical enclosure for the Gravity Reactor's subsurface systems. The borehole structure also implements steel casing cemented in place along the full depth of the approximately one-mile borehole. The steel casing enhances the structural integrity of the borehole structure and creates a consistent inner surface to the geological formation. The cement annulus between the casing and the host rock bonds the casing in place and provides additional structural support.

The casing and cement structure is designed and installed using methods adapted from well-established commercial deep drilling and well completion practices. Site selection criteria for the borehole structure ensure that the reactor is placed well below potable groundwater aquifers where subsurface waters are hydraulically isolated and immobilized within the rock formation. The geological isolation provided by the borehole structure, combined with the added casing and cement barrier, contributes to the plant's overall defense-in-depth strategy by limiting the potential for radionuclide transport to the surface environment in the unlikely event of a primary system release at depth.

Long-term structural integrity of borehole structure will be monitored over the operational life of the plant using well integrity assessment techniques adapted from the deep drilling industry. These may include pressure testing, casing inspection logging, and monitoring of borehole water chemistry for indicators of degradation or breach.

2.2.1.7 Borehole Closure

The borehole closure (BC) device structurally supports the subsurface reactor systems and serves as the mechanical and pressure boundary interface between the subsurface systems and the surface facilities; it functions analogously to a wellhead in commercial deep drilling applications. The closure device is welded to the top edge of the borehole casing at grade and provides the structural termination point for the entire suspended subsurface assembly, including the reactor canister and internals, PHX, PP, and underground SP. The suspended load is carried through a threaded premium connection between the SP VIT string and the closure device, a proven connection method used routinely in deep borehole and well drilling operations.

The closure device incorporates multiple penetrations to accommodate the various systems that interface between the surface and subsurface, including the secondary coolant VIT, PCC lines, instrumentation and electrical cable bundles, and BWC connections. Pressure-sealed penetrations maintain the integrity of the borehole pressure boundary at the wellhead. A connection tree mounted on top of the closure device provides the flow path interfaces for the heated and cooled secondary coolant streams entering and exiting the borehole, along with isolation valving for each circuit.

The BC device structurally supports the subsurface reactor systems and maintains the pressure boundary of the borehole. It withstands the full hydrostatic pressure of the water column at depth as well as the mechanical loads imposed by the suspended reactor assembly. The plant's ongoing maintenance program includes routine inspection and functional testing of the closure device, its seals, and its associated valving.

2.2.1.8 Borehole Water Control

The BWC system supports management of borehole water temperature and chemistry within the annulus surrounding the reactor and primary systems. During normal plant operation, the borehole water serves multiple important functions. It provides a passive heat sink, the hydrostatic pressure equilibrium that is fundamental to the Gravity Reactor's operation, and acts as a radionuclide scrubbing and retention volume in the unlikely event of a primary system release. The BWC system is used during normal operations to maintain borehole water parameters to be predictably within desired ranges.

Borehole water chemistry supports both corrosion inhibition and reactivity management. The BWC system supports the maintenance of borehole water chemistry by providing one means of chemical addition to the borehole water (e.g., boric acid, lithium hydroxide). The BWC is used to help manage pH, dissolved oxygen, and other water quality parameters to limit corrosion of submerged metallic components over the plant's operational lifetime. Dedicated sample lines interfacing with the BC device at the surface enable periodic sampling and analysis of borehole water chemistry.

The BWC system is used to monitor and maintain control of temperature and pressure of the borehole water to support operational objectives. The BWC system also manages gas accumulation within the borehole water, with any normally evolved gases collected, sampled, and routed to the plant's gaseous waste subsystem for controlled management in accordance with 10 CFR Part 835, “Occupational Radiation Protection,” and NE O 435.1, “Radioactive Waste Management.”

2.2.1.9 Module Control

The MC system integrates monitoring and control functions into a centralized, surface-based control center. Operators use the MC system to monitor neutron flux, coolant temperatures, pressures, flow rates, and chemical compositions. The system collects data from sensors distributed throughout the reactor, piping, and surface systems.

Through its user interface, the MC system enables operators to issue commands, such as adjusting coolant chemistry or regulating secondary flow. The MC system automatically initiates protective actions when it detects anomalies - such as abnormal neutron flux or pressure deviations. It maintains continuous operation with redundant power supplies and data backups. The MC system also serves as the primary data acquisition platform for validating reactor physics and system performance.

2.2.1.10 Radioactive Waste

The radioactive waste system collects, processes, stores, and prepares for disposal radioactive liquid, gaseous, and solid wastes generated during normal plant operations and anticipated transients. The primary source of liquid radwaste is water removed from the primary coolant system via the PCC lines, along with any applicable equipment leak offs and floor drains. Operators sample and analyze these streams, then process them through filtration, demineralization, and evaporation as appropriate, before controlled release or solidification for disposal. Deep Fission handles all radioactive wastes generated on site in accordance with 10 CFR 835 and NE O 435.1.

The gaseous radwaste subsystem manages fission product noble gases and tritium that may evolve from the primary coolant, holding them up in delay beds or charcoal adsorbers to allow decay prior to monitored release. Deep Fission segregates, characterizes, and packages solid wastes — including spent resins, filter media, and dry active waste generated during operations and maintenance — for transfer to an appropriate DOE-authorized disposal facility consistent with the requirements of NE O 435.1.

2.2.2 Operational Design

2.2.2.1 Depth and Pressure

The Gravity Reactor operates at depth, within a borehole, geologically isolated from the surface, and under the hydrostatic head from a mile long column of water. This design maintains stable system pressurization without the use of mechanical means; the operating pressure of the reactor is balanced with the pressure of the surrounding borehole water. In addition, this configuration passively and reliably contains, confines, and mitigates any potential releases of radionuclides.

This pressure-balanced design further enhances safety by removing the potential for rapid depressurization events. If a leak occurs, external water pressure matches the internal coolant pressure, preventing sudden coolant loss or depressurization. The geology at the site is defined by low seismicity and well-characterized rock formations. The act of drilling the borehole provides unparalleled insight into geological conditions. This provides a stable foundation that supports the reliability of the reactor's design and configuration and results in minimal risk of operational disturbances or transients initiated by natural phenomena.

2.2.2.2 Controls

The Gravity Reactor uses both physical and procedural barriers to protect the public and workers. A system continuously monitors neutron flux, pressure, and temperature. If the system detects an abnormal condition, operators use defined control strategies to address the potential hazard and reduce its consequences to acceptable levels.

Natural circulation and convection remove heat, passively controlling coolant temperature while the hydrostatic column prevents coolant loss. Administrative controls complement these design features, requiring dual verification of adherence to operational protocols for operator actions that are important to safety. Together, these layers of protection ensure safe performance under expected and off-normal conditions.

2.3 Life Cycle Concept of Operations

The Gravity Reactor has several operational modes during its life cycle. Each mode described in this section represents a step in the reactor life cycle, from borehole test and verification to decommissioning.

2.3.1 Borehole Test and Verification

Deep Fission conducts pressure testing and dimensional verification of the borehole prior to reactor installation to ensure borehole integrity and tolerance requirements.

2.3.2 Reactor Assembly and Test on Surface

Deep Fission conducts hydrostatic pressure testing on the reactor canister prior to installation of fuel. A team assembles and tests RI and associated systems at the surface before deployment. During this mode, the reactor remains subcritical and voided of water, ensuring no potential for criticality. Test engineers and technicians verify system integrity through leak checks, sensor calibration, and control logic testing under ambient conditions.

2.3.3 Reactor Deployment Down Borehole

After successful surface testing, Deep Fission begins reactor deployment into the borehole. Operators fill the reactor canister with borated water from a verified source to maintain subcriticality during lowering. Installers control descent speed and alignment to prevent damage. Once submerged, operators maintain the borehole water level above the reactor to preserve hydrostatic pressure and coolant stability. This phase establishes safe emplacement conditions and verifies the integrity of subsurface interfaces before startup operations begin.

2.3.4 Cold Shutdown

In cold shutdown mode, the reactor remains subcritical. Operators maintain system chemistry, pressure, and temperature through the PCC and secondary coolant control systems.

Technicians perform post-lowering inspections and testing of surface systems, verify instrumentation readings, and confirm borehole stability before proceeding to startup. This controlled subcritical phase allows engineers to establish safe operating baselines and verify the hydrostatic pressure environment is stable and balanced prior to criticality approach.

2.3.5 Reactor Startup

Prior to initiating reactor startup, operators complete and document pre-operational checks and system readiness verifications in accordance with approved procedures. This includes confirmation that the BC device is fully secured, BWC system parameters are within normal operating bands, downhole I&C systems are functional and communicating with the surface instrumentation hub, and secondary coolant flow is established. Primary coolant chemistry, including boron concentration, is verified to be within the specified startup range prior to initiating any reactivity changes.

Operators initiate reactor startup by a controlled reduction in primary coolant boron concentration via the PCC system, reducing the concentration of soluble boron (i.e., neutron absorber) in a slow and deliberate manner consistent with approved startup rate limits. Neutron flux is monitored continuously throughout the startup sequence using the downhole instrumentation, with operators tracking the inverse count rate ratio to project the approach to criticality. Any unexpected deviation in neutron behavior, coolant temperature, pressure, or borehole water parameters requires the startup sequence to be paused and evaluated before proceeding. The startup phase is considered complete when the reactor approaches the point of criticality and is ready for transition to the Reactor Critical phase.

2.3.6 Reactor Critical

In reactor critical mode, the Gravity Reactor achieves controlled zero-power criticality. This is characterized by slow and steady neutron increase and a long reactor period[a]. The team uses the MC system to monitor neutron flux, coolant behavior, borehole water level, and chemistry, ensuring stable operations and response to any parameter drift.

Operators collect instrument data to validate reactor models and confirm safe performance. The reactor operates at zero-power criticality for a short period, proving a reactor can achieve and maintain criticality safely in a deep borehole environment.

2.3.7 Power Ascension

Following successful demonstration of stable zero-power criticality, the reactor transitions to the power ascension phase, during which reactor thermal output is incrementally raised toward full rated power. Operators conduct power ascension in a stepwise fashion, with hold points defined at prescribed power levels to allow operators to collect steady-state data, verify thermal-hydraulic behavior, and confirm that instrumentation readings are consistent with predicted performance. At each hold point, Deep Fission evaluates natural circulation flow characteristics, primary coolant temperatures, PHX performance, and secondary coolant system response before authorizing the next power increase.

Power ascension testing serves as the primary opportunity to validate the reactor's passive thermal-hydraulic behavior under actual operating conditions, including confirmation of natural circulation stability, temperature reactivity feedback responses, and the performance of the BWC system under increasing heat loads. Any anomalous behavior identified during a hold point — including unexpected reactivity trends, flow instabilities, or elevated borehole water temperatures — requires evaluation and resolution before power escalation continues. The power ascension phase is considered complete when the reactor has achieved full rated thermal power and all monitored parameters have been confirmed stable within their normal operating limits.

2.3.8 Power Operation

During normal power operation, the Gravity Reactor operates continuously at or near its rated thermal output, with the primary coolant system driven by natural circulation and secondary and tertiary coolant systems maintained by their respective pumps and associated instrumentation and controls. Operators monitor plant performance from

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[a] The reactor period is the rate at which the reactor power (or neutron population) is changing over time.

the surface control facility using data provided by surface and downhole instrumentation, with particular attention to primary coolant temperature, pressure, and chemistry, borehole water parameters, secondary system flow and heat transfer performance, and power conversion system output. Deep Fission performs routine surveillance and testing of operable systems in accordance with approved technical specifications and the plant's surveillance test program.

Periodic sampling and analysis of primary coolant chemistry via the PCC lines confirms that boron concentration, pH, and corrosion product levels remain within specified limits. Continuous management of borehole water chemistry and temperature by the BWC system maintains corrosion inhibition, reactivity margin, and protection of downhole I&C equipment. Any parameter trending toward a procedural action level initiates a defined operator response, which may include chemistry adjustment, power reduction, or controlled shutdown depending on the nature and severity of the deviation. Power operation continues until a planned or unplanned condition requires transition to the Power Down phase.

2.3.9 Power Down

Power Down consists of the controlled reduction of reactor thermal output from power operation to a subcritical, decay heat removal condition. Operators initiate a planned power down by gradually increasing primary coolant boron concentration via the PCC system, introducing negative reactivity at a controlled rate and reducing fission power in a stepwise manner consistent with approved procedures. Secondary and tertiary coolant systems remain in service throughout the power reduction to continue removing heat from the primary system. Operators monitor the rate of power decrease, coolant temperatures, and natural circulation behavior to confirm that the reactor is responding as expected at each step.

Once fission power has been reduced to zero and the reactor is confirmed subcritical with adequate shutdown margin verified, the plant transitions to decay heat removal mode. The borehole water column and surrounding geological formation serve as passive heat sinks for decay heat removal, supplemented by continued secondary coolant flow as needed during the early post-shutdown period. Operators closely monitor BWC system parameters following shutdown, as reduced primary system heat output will affect borehole water thermal stratification and circulation patterns. The Power Down phase is considered complete when decay heat levels have decreased to the point that passive geological cooling alone is sufficient to maintain all subsurface temperatures within acceptable limits and the plant is in a stable, long-term shutdown condition.

2.3.10 Reactor Outage

Reactor outage represents a planned or unplanned interruption of reactor operation. For the pilot, planned outages occur only as part of the scheduled criticality demonstration sequence, while unplanned outages result from anomalies such as sensor faults, unexpected parameter changes, or system shutdowns.

In either case, operators execute shutdown procedures to ensure subcriticality. The MC system records event data for analysis. Deep Fission then inspects surface systems, verifies coolant chemistry, and performs safety checks before authorizing re-entry into startup or shutdown modes. These controlled responses reinforce the project's emphasis on operational discipline and continuous safety assurance.

2.3.11 Used Fuel Handling and Storage

Used fuel remains in the borehole within the suspended reactor canister, which provides the primary confinement boundary and structural support for both operational and post-irradiation conditions. This solution does not require any transfer of fuel assemblies to a separate storage container. The borehole environment supports the canister and provides passive heat removal through conduction to the surrounding geologic media and natural convection within the borehole fluid. The design ensures criticality safety through fixed fuel geometry and, where applicable, neutron-absorbing materials incorporated into the canister. The water column and overlying geologic materials provide additional radiation shielding. Together, the canister, borehole fluid, and surrounding geologic formation provide a multi-barrier approach to confinement.

Deep Fission may retrieve used fuel throughout the storage period via established and repeatable mechanical methods. The retrieval process relies on proven technologies used in deep-well operations. The design provides sufficient margins to accommodate off-normal conditions, while maintaining the ability to safely monitor, access, engage, and extract used fuel. The used fuel remains in a managed, retrievable configuration that does not preclude subsequent transportation or disposition in accordance with applicable regulatory requirements.

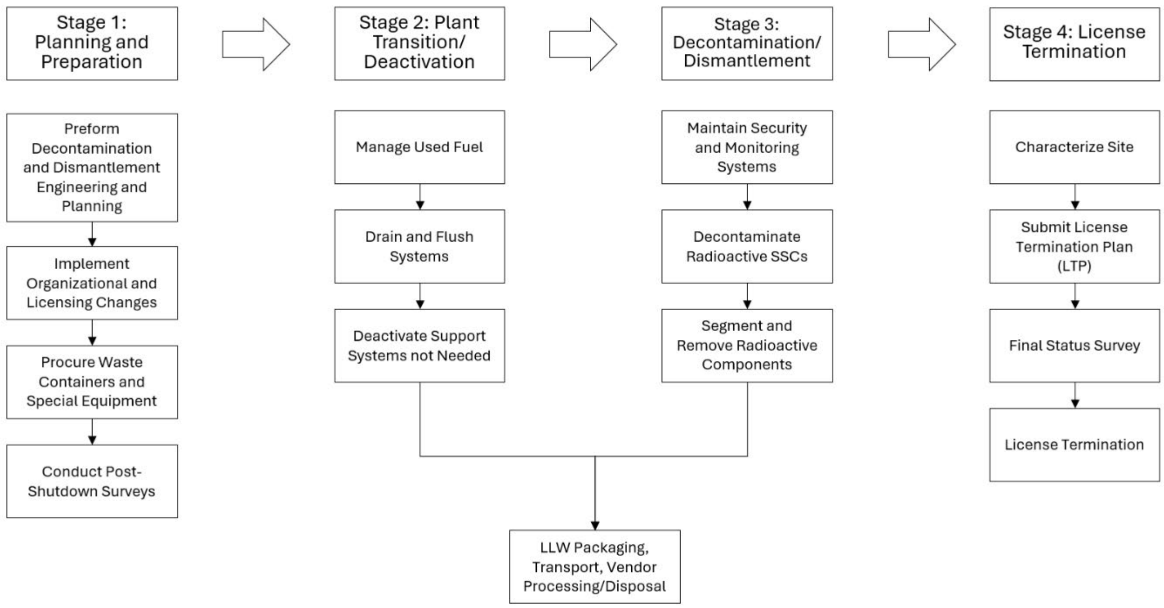
Future Interim Storage Licensing (Disclosure):

> Deep Fission may use the borehole or a surface-based facility to support extended interim storage of irradiated fuel beyond the operational needs addressed in this application. However, the current licensing basis does not include an independent spent fuel storage installation, which would apply to used fuel that has decayed for at least one year.

2.3.12 Decontamination and Decommissioning

Decontamination and decommissioning (D&D) of the facility and site represent the final phase of the plant operations life cycle. To support this effort, Deep Fission secured a site lease with a 99-year base term and options to extend for up to two additional 25-year periods (149 years total). Deep Fission's D&D approach includes the provision of qualified personnel, implementation of applicable safety management programs, and allocation of sufficient financial resources. The Phase II agreement under the Other Transaction Agreement (OTA) – to be negotiated between DOE and Deep Fission at the conclusion of Phase I – will define the path forward, including either decommissioning of DOE-authorized facilities, transition to commercial licensing with the NRC, or another mutually agreed upon scope.

D&D of the reactor system includes the cessation of reactor operations, reduction of residual reactivity to acceptable levels, and decontamination and disposition of associated structures and systems. Figure 2 shows the anticipated reactor decommissioning process.



Derived from NUREG-0586 Supplement 1, GEIS on Decommissioning of Nuclear Facilities, Volume 1, 2002, pg. 3-34 https://www.nrc.gov/docs/ML0234/ML023470304.pdf

Figure 2: Anticipated Reactor Decontamination and Decommissioning Process

The reactor D&D process follows a structured, multi-stage approach that transitions the facility from operation to full license termination. Beginning with planning and preparation, Deep Fission performs detailed engineering for decontamination and dismantlement, implements organizational and licensing changes, procures specialized equipment, and conducts post-shutdown surveys. Next, during plant transition and deactivation, operators transfer used fuel into secure storage, drain and flush systems, and deactivate non-essential support systems. The process then advances to decontamination and dismantlement, where crews maintain safety and monitoring systems while they decontaminate, segment, and remove radioactive SSCs, packaging and transporting low-level waste for disposal through approved vendors. Finally, in license termination, Deep Fission characterizes the site, submits a license termination plan, performs a final status survey to confirm compliance with radiological criteria, and completes the process by permanently plugging the borehole using established industry methods and terminating the facility's operating license.

2.4 Inspections and Maintenance

Primary system components — including the reactor canister, internals, PHX, and PP — reside approximately one mile below grade. Routine condition monitoring of these components relies heavily on in situ instrumentation, including downhole sensors for temperature, pressure, flow, and coolant chemistry. Deep Fission leverages remote inspection technology developed in the drilling industry where appropriate. Periodic retrieval of the reactor module to the surface using the overhead rig system, analogous to well workover operations in the commercial drilling industry, may be implemented to support hands-on inspection and maintenance activities.

Surface systems include the BC device, secondary coolant piping and pumps, secondary heat exchanger, power conversion equipment, and I&C systems. Inspection and maintenance activities for these systems follow standard maintenance practices, including periodic functional testing, calibration of instrumentation, valve and pump maintenance, and structural inspection of the wellhead and closure assembly. Monitoring the integrity of the borehole casing and cement structure occurs over time using methods adapted from the well integrity assessment practices common in the deep drilling industry.

Given the reliance on natural circulation in the primary coolant system and passive safety features, Deep Fission gives particular attention to monitoring for fouling, corrosion, or scaling within the primary circuit that could affect flow characteristics or heat transfer performance. Primary coolant chemistry gets routinely sampled and analyzed via the PCC lines to detect changes indicative of fuel cladding degradation or system corrosion. Maintenance activities involving the subsurface systems require detailed pre-planning to manage radiation exposure to workers consistent with the requirements of 10 CFR Part 835 utilizing retrieval and handling procedures developed to minimize dose and contamination spread.

3 Safety Analysis Preparations

The Gravity Reactor implements safety analysis processes for the pilot that provide reasonable assurance of adequate protection of the health and safety of the public and workers. This safety analysis process has been appropriately tailored, simplified, and streamlined to facilitate efficient review and approval. DOE holds the authority to approve the design, fabrication, construction, operation, and testing of the Gravity Reactor and its SSCs. Therefore, with its safety analysis framework for the pilot, Deep Fission intends to fully meet the outcome objectives of 10 CFR Part 830. To ensure additional analytical rigor and conservatism and to prepare for subsequent commercialization of the Gravity Reactor design, Deep Fission safety analysis also considers the outcome objectives of 10 CFR Part 50, 10 CFR Part 52, 10 CFR Part 53, etc.

The Gravity Reactor is a light-water cooled, light-water moderated, PWR design, which implements conventional PWR fuel within typical commercial PWR operational temperature and pressure ranges. As such, the core neutronics, thermal-hydraulics, possible transients, and subsequent radioactivity transport pathways are well-analyzed and well-understood. Due to this straightforward reactor design, analytical methodologies with extensive pedigree for LWRs can be leveraged to support the development of the Gravity Reactor's safety analysis. In addition to its implementation of familiar reactor technology, Deep Fission designed the Gravity Reactor to be geologically isolated approximately one mile underground and immersed within a hydrostatic column of water. These design features simplify the maintenance of operational parameters (i.e., temperature and pressure) and provide passive protection to the public, workers, and environment from the consequences of off-normal events.

3.1 Fundamental Safety Functions

Following DOE-STD-1271-2025, “Authorization Pathway for Nuclear Facilities,” Deep Fission aligns its design with the guiding principle of protecting the health and safety of the public and workers. The design provides reasonable assurance of adequate protection by ensuring the following fundamental safety functions:

- Radioactive material confinement
- Nuclear reactivity control
- Fission and decay heat removal
- Preservation of adequate radiation shielding

Using the early identification of fundamental safety functions, by name, to drive the design of safe nuclear reactors is an effective concept that has been largely implemented and popularized internationally. Domestically, for currently operating power reactors, deterministic analyses are performed to identify the safety functions necessary to ensure that hazards presented by operating the reactor are controlled and to provide reasonable assurance that the health and safety of the public and workers is protected. Then, for the controls that fulfill those necessary safety functions, performance expectations are established to ensure that they perform as designed.

With this understanding, Deep Fission comprehensively addresses the fundamental safety functions in the Gravity Reactor’s design-specific principal design criteria (PDC). The PDC flow from the General Design Criteria (GDC) framework of 10 CFR Part 50 Appendix A (see Table 1)[b] and meet all applicable outcome objectives of the design criteria set forth in NE Order 420.1, “Facility Safety.” Specifically, the Gravity Reactor fulfills fundamental safety functions and applicable PDC by a combination of inherent or natural passive (INP) design features. Nevertheless, Deep Fission includes additional SSCs in the Gravity Reactor design to add layers of protection for the public, workers, and environment (i.e., defense-in-depth). The design for SSCs that serve fundamental safety functions satisfies the PDC to provide reasonable assurance that the Gravity Reactor can operate without undue risk to the health and safety of the public and workers. Table 1 shows the GDC categories that address each fundamental safety function as well as INP design features and the notional allotment of SSCs that fulfill those functions.

The Gravity Reactor design minimizes the need for engineered SSCs to prevent the progression of postulated design basis events (DBEs). Instead, the Gravity Reactor leverages unique and reliable natural site characteristics that establish favorable initial conditions for the analysis of postulated events. These site characteristics perform key safety functions far more reliably than any engineered SSC, and they allow for foundational inputs and assumptions to analyses that significantly limit, and in some cases eliminate, the consequences of postulated accidents. Specifically, siting of the Gravity Reactor always includes the selection of a deep borehole that becomes part of

b. GDCs guide the identification of principal design criteria for the Gravity Reactor, informed by 10 CFR 50.34 (a)(3) and 10 CFR 52.47(a)(3).

the reactor's design. This borehole provides geological isolation of the reactor and its associated source term. In addition, this borehole maintains a hydrostatic water column above the reactor nominally one mile tall. These features passively provide safety functions that both prevent and mitigate the release and transport of radioactive material from the Gravity Reactor core in the event of hypothetical transients. These design decisions enhance safety and are unique to the Gravity Reactor.

Table 1: Fundamental Safety Functions Correlation to SSCs and GDCs

Fundamental Safety Function	General Design Criteria Category	Notional SSCs	Inherently or Natural Passive Design Feature
Radioactive Material Confinement	II. Protection by Multiple Fission Product Barriers V. Reactor Containment	Fuel Matrix Fuel Cladding Reactor Canister Primary Coolant Boundary	Geological Isolation Hydrostatic Water Column
Nuclear Reactivity Control	III. Protection and Reactivity Control Systems	Primary Coolant Control System Aqueous Reactivity Control and Shutdown System Neutron Monitoring	Negative Reactivity Feedback (e.g., temperature coefficient, Doppler broadening) Hydrostatic Water Column (when mixed with soluble neutron absorber)
Fission and Decay Heat Removal	IV. Fluid Systems	Secondary Coolant Boundary Tertiary Coolant System	Geological Isolation Hydrostatic Water Column
Preservation of Adequate Radiation Shielding	II. Protection by Multiple Fission Product Barriers VI. Fuel and Radioactivity Control	Borehole Structure	Geological Isolation Hydrostatic Water Column

3.2 Safety Analysis Process

Deep Fission's safety analysis process for the Gravity Reactor systematically evaluates potential transients and accidents, including postulated disturbances in process variables and postulated equipment failures or malfunctions. In doing so, the safety analysis provides the basis for selecting controls – such as SSC design specifications, limiting conditions for operation, and limiting control settings – from the standpoint of public health and safety.

As previously described, the Gravity Reactor is a PWR design that operates at typical temperatures and pressures, uses only a fraction of the conventional fuel loading, and is geologically isolated deep underground. The hazards associated with its operation are well known, and it is designed to passively mitigate the consequences of postulated accidents. However, any SSCs that fulfill fundamental safety functions leverage the GDC and use established design principles.

Over the last 70 years, industry and regulators have identified and evaluated a broad spectrum of potential transients and accidents applicable to light-water reactors (LWRs) in general and PWRs specifically. Deep Fission's safety analysis process leverages this extensive body of work and applies approved methods endorsed by both the DOE and NRC – methods used many times to authorize and license LWRs.

To identify transients and accidents unique to the Gravity Reactor design, analysts choose from a selection of multiple methods including hazard and operability study, failure modes and effects analysis, and hazard-identification checklists, DOE-HDBK-1163-2020, "Integration of Hazard Analyses," Appendix A Figure A-2 and DOE-HDBK-1224-2024, "Hazard and Accident Analysis Handbook." The evaluation process reveals initiating events for DBEs. Based on the low risk profile of currently planned design and operational parameters for the RPP, Deep Fission does not anticipate the need to use a probabilistic risk assessment (PRA) to support evaluation of any new or unique DBEs, as several other systematic risk evaluation methodologies exist for application to the Gravity Reactor design, if needed.

Deep Fission uses a systematic and reproducible framework for selecting design basis accidents (DBAs), identifying safety-related SSCs, and determining the adequacy of the defense-in-depth strategy. The safety analysis process implements steps informed by the regulatory framework prescribed in 10 CFR Part 50 and 10 CFR Part 52. In this way, Deep Fission meets the outcome objectives of 10 CFR Part 830. See Figure 3.

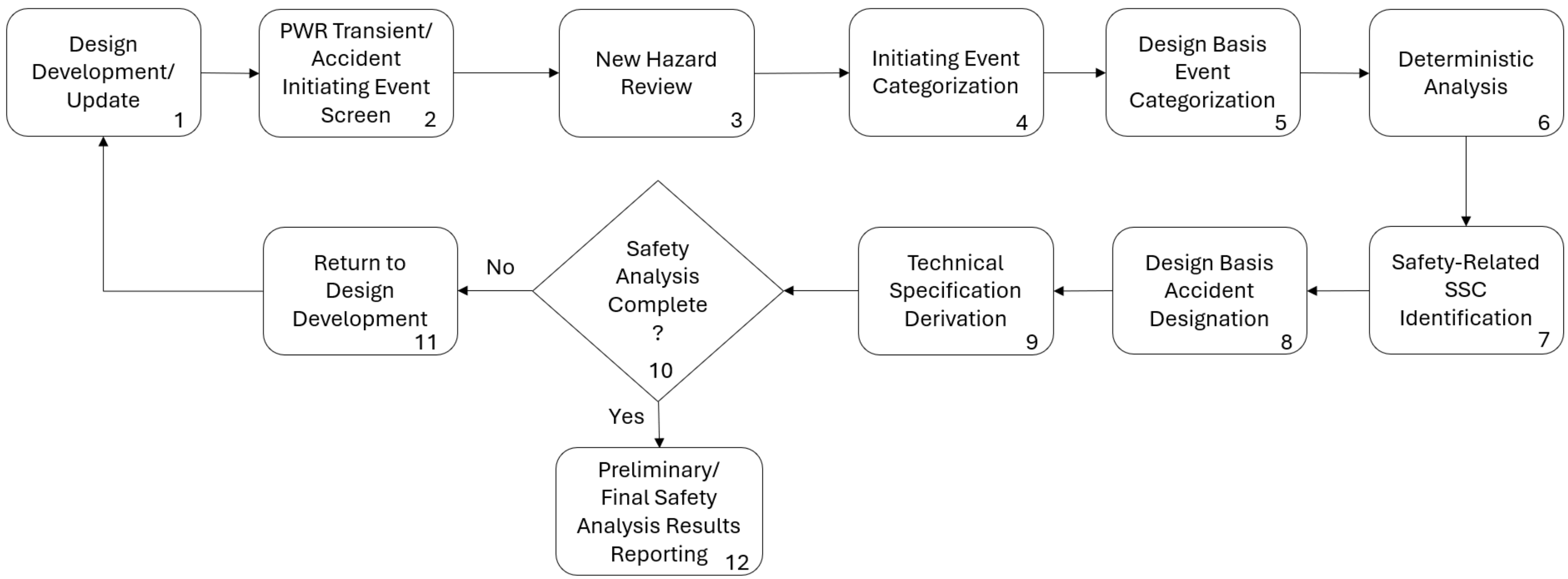


Figure 3: Safety Analysis Process

Deep Fission constructs and informs its safety analysis process using elements from DOE and NRC guidance documents as well as other industry standards, including:

- NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports"
- RG 1.206, "Applications for Nuclear Power Plants"
- NE-STD-1027-2025, "Hazard Categorization of DOE Nuclear Facilities"
- DOE-STD-1271-2025, "Authorization Pathway for Nuclear Facilities"
- DOE-STD-1189-2016, "Integration of Safety into the Design Process"
- NE Order 420.1, "Facility Safety"
- DOE-HDBK-1163-2020, "Integration of Hazard Analyses"
- DOE-HDBK-1224-2024, "Hazard and Accident Analysis"
- RG 1.253, "Guidance for a Technology-Inclusive Content-of-Application Methodology to Inform the Licensing Basis and Content of Applications for Licenses, Certifications, and Approvals for Non-Light-Water Reactors"
- RG 1.183, "Alternative Radiological Source Terms for Evaluating Design Basis Accidents at Nuclear Power Reactors"
- 10 CFR Part 830.203, "Unreviewed safety question process"
- DOE G 424.1-1C, "Implementation Guide for Use in Addressing Unreviewed Safety Question Requirements"
- 10 CFR Part 50.59, "Changes, tests, and experiments"
- 10 CFR Part 50.36, "Technical specifications"
- NUREG-143X series for Improved Standard Technical Specifications
- American Society of Mechanical Engineers (ASME) Plant Systems Design Standard (PSD)-1 (2025), "Integrating Systems Engineering and Plant Design."

Table 2 outlines the Gravity Reactor safety analysis process.

Table 2: Safety Analysis Process Description

Step Number	Step Name	Description
1	Design Development and Performance-Based Entry Screening	Examine the current design against the fundamental safety functions; define plant operating states; develop the principal design criteria (PDC) using the RG 1.232 cross-walk methodology, with cross-reference to the Part 50, Appendix A, GDC; evaluate and qualify the credited inherent or natural passive (INP) design features; perform the entry-screening evaluation; and select the MHA or MCA methodology for Step 6. Product: Safety Design Approach Report (SDAR).

Step Number	Step Name	Description
2	PWR Transient/Accident Initiating Event Screen	Screen the initiating event categories against the Gravity Reactor design and its credited INP design features. Capture each applicability determination, including the technical basis for any event determined to be precluded by an INP design feature or by a fundamental design difference. Product: Initial population of the master initiating event list in the DBE Identification and Categorization Report (DICR).
3	New Hazard Review	Identify hazards unique to the Gravity Reactor configuration (e.g., INP design features, deep-borehole emplacement, hydrostatic water column) and add the resulting new initiating events to the master initiating event list created in Step 2. Use structured deterministic methods (e.g., What-If Analysis, HAZOP, FMEA) supplemented as needed by the alternative methodology (e.g., AERI methodology of NRC DG-1414). Product: Revised and augmented master initiating event list in the DICR, with supporting hazard-analysis reports.
4	Initiating Event Categorization	Characterize each initiating event (what initiates it, the plant operating state, the equipment or human action involved, and the fundamental safety function first challenged) and categorize each as an anticipated operational occurrence (AOO) or a postulated accident. Product: Revised and categorized master initiating event list in the DICR.
5	Design Basis Event Categorization	Assign each AOO and postulated accident to groups or families. Identify the bounding postulated accident within each family for the Step 6 deterministic analysis; disposition with documented bases those postulated accidents that cannot result in fuel damage, radionuclide release, loss of a credited barrier, or a release pathway not already bounded. Product: Event family-categorized, bounding-event-identified DICR.

Step Number	Step Name	Description
6	Deterministic Analysis (Including MHA/MCA Selection)	Perform the deterministic accident analyses on the bounding postulated accidents using conservative assumptions consistent with NUREG-0800, Sections 15.0.1 through 15.0.3, the AST methodology of RG 1.183, and the dispersion modeling guidance of RG 1.145 (and RG 1.194/RG 1.249 as applicable). Analyze the facility-wide MHA (or MCA). Product: Controlled set of deterministic accident analysis calculations and the facility-wide MHA (or MCA) analysis.
7	Safety-Related SSC Identification	Identify, from the Step 6 deterministic analyses, the SSCs and credited INP design features required to keep dose consequences below 1 rem (0.01 Sv) TEDE. Classify each SSC as "safety-related" per the three-pronged definition cited in this document, as tailored specifically to the Gravity Reactor design; classify supporting SSCs as important to safety where appropriate. Identify credited INP design features as site characteristics necessary to establish initial conditions. Assign measurable, verifiable PDCs to each safety-related SSC using the RG 1.232 methodology. Optionally, inform risk-informed categorization with RG 1.201. Product: Safety-Related SSC Identification Report.
8	Design Basis Accident Designation	Designate as Design Basis Accidents (DBAs) those postulated accidents that require credit for a safety-related SSC (or a credited INP design feature) to keep dose consequences below criterion. For each DBA, document the initiating event, the operating state(s), the credited safety functions, the SSCs and INP features that perform them, the timing and source term assumptions, the dose consequence result, and the applicable acceptance criteria (with Part 50 cross-references). Carry forward the MHA designation as the bounding facility-wide accident. Product: DBA Designation Report.

Step Number	Step Name	Description
9	Technical Specification Derivation	Apply the four-criterion LCO screening of 10 CFR 50.36(c)(2)(ii), as adapted by Deep Fission, to identify LCO scope. Derive Safety Limits, Limiting Safety System Settings, Surveillance Requirements, Design Features (locking in credited INP characteristics under NUREG-1431, Section 4.0, and 10 CFR 50.36(c)(4)), Administrative Controls, and LCO completion times consistent with the NUREG-1431 standard technical specifications template; and (optionally) the SFCP of NEI 04-10 and the risk-informed completion-time guidance of RG 1.177. Develop a supporting Bases for each Technical Specification. Product: Draft Technical Specifications and supporting Bases.
10	Safety Analysis Completion Check (Including Defense-in-Depth Evaluation)	Evaluate the safety-analysis products against an explicit completeness checklist. Perform the defense-in-depth evaluation. Determine whether to proceed to Step 11a (PSAR issuance) or Step 11b (return to design). Product: Safety Analysis Completion Checklist (SACC) and the proceed-to-Step-11a-or-11b determination.
11a	Report Preliminary Results	Assemble and issue the PSAR for review. The PSAR incorporates, by reference or inclusion, the SDAR, DICR, deterministic analyses and MHA analysis, Safety-Related SSC Identification Report, DBA Designation Report, draft Technical Specifications, and SACC. Product: Preliminary Safety Analysis Report (PSAR).
11b	Return to Design Development	Return the process to Step 1 (Design Development) with a documented basis for the return identifying each gap from Step 10, the affected safety-analysis products, and the required disposition. Preserve configuration control consistent with the NQA-1 SDAR-to-FSAR document control requirements. Product: Controlled return-to-design action set and configuration-management record.

Step Number	Step Name	Description
12	Report Final Results	Develop the FSAR by updating the PSAR consistent with the as-built/as-to-be-operated configuration and with any changes processed through configuration control since PSAR issuance. Product: Final Safety Analysis Report (FSAR).
	Document Technical Specifications	Finalize and issue the Technical Specifications as a controlled document linked to the FSAR, including Safety Limits, Limiting Safety System Settings, Limiting Conditions for Operation, Surveillance Requirements, Design Features (preserving credited INP characteristics), Administrative Controls, and supporting Bases. Product: Final Technical Specifications and supporting Bases.

3.3 Quality Management System Implementation

The project team confirms the adequacy of analytical results through the processes defined in Deep Fission's quality management system and the project-specific controls described in Deep Fission quality assurance program (QAP). Software used to support safety analyses is controlled in accordance with the quality assurance criteria in NE Order 414.1, "Quality Assurance," including requirements for software selection, configuration control, verification, validation, and documentation.

Deep Fission's current analytical work relies primarily on unmodified commercial off-the-shelf software. These tools support early estimates and assessments of postulated dose consequences, radiological source terms, transport behavior, dispersion impacts, and criticality accident scenarios. During this development phase, calculations used to inform design decisions or support NSDA deliverables follow the graded approach described in the quality assurance program plan and defined in the Deep Fission QAP, which includes confirming the suitability of the software for the intended application, identifying key assumptions and computational limitations, maintaining traceable calculation packages, and performing independent technical reviews at the appropriate level of rigor.

Before any analytical output is used to support future nuclear safety documents, Deep Fission completes the required software validation steps. Once validated, these codes form the analytical basis for source term development, radioactivity transport modeling, dispersion modeling, criticality evaluations, and related-safety analyses as the RPP advances.

4 Safety Document Format and Content

In accordance with 10 CFR Part 830 Appendix A Table 1, the documented safety analysis (DSA) format and content generally follow the safe harbor guidance in NRC RG 1.70, "Standard Format and Content of Safety Analysis Reports for Nuclear Power Plants," and its successor documents (e.g., RG 1.206 and RG 1.253). Implementing this guidance first produces a preliminary safety analysis report (PSAR) and then a final safety analysis report (FSAR), which documents the safety analysis and the basis for authorizing reactor operation. In addition, DOE-STD-3009-2014, "Preparation of Nonreactor Nuclear Facility Documented Safety Analysis," will be used to help guide discussion of how the safety analysis addresses worker protection.

This approach will simplify the safety evaluation of the safety analysis, as it aligns with all Category A (Hazard Category 1) and many Category B (Hazard Category 2) nuclear reactors that DOE authorizes and operates. In addition, the safety analysis format and content are, in part, informed by standard review plan (SRP) guidance in NUREG-0800; leveraging an established framework will help to facilitate the safety evaluation of the safety analysis.

5 Regulatory Engagement Process

Deep Fission's regulatory engagement process describes a clear, integrated, DOE-controlled regulatory pathway. It ensures Deep Fission and DOE identify safety and regulatory requirements early through joint engagement; Deep Fission integrates these requirements into the reactor's design, construction, and operation; and DOE verifies them through formal approvals. This process also includes direction for interaction with state, local, and tribal (SLT) stakeholders (e.g., for pilot site permits and outreach) and establishes observation opportunities for NRC, intended to facilitate future commercial licensing of Deep Fission reactors.

5.1 Core Principles

Core principles for the process and its implementation include:

1. **Integration of Safety into Design –** Deep Fission and DOE integrate safety requirements and regulatory reviews into design activities in accordance with the design and authorization integration process in DOE-STD-1271-2025.

2. **DOE Control and Oversight –** DOE acts as both the Safety Basis Approval Authority (SBAA) and the Startup Approval Authority, exercising regulatory control over the design, construction, and initial operation of the reactor.

3. **Transparent and Frequent Engagement –** Continuous communication and frequent meetings with the DOE Review Team ensure rapid issue resolution and regulatory certainty.

4. **Equivalency and Flexibility –** Where appropriate and if approved by the SBAA, Deep Fission may use NRC regulations, industry standards, or self-generated equivalents (consistent with performance-based attributes).

5. **Observation by NRC and Transition to NRC Oversight** – During the pilot, NRC will observe Deep Fission's work without diminishing DOE's regulatory authority. After the pilot, Deep Fission anticipates a transition of regulatory control from DOE to NRC for commercial licensing, expanded construction, operation, and eventual decommissioning.

5.2 Engagement and Deliverables

Deep Fission systematically develops, and DOE approves, key deliverables as the project advances through critical milestones. Key deliverables include this NSDA, preliminary documented safety analysis (PDSA)/PSAR, quality assurance program description (QAPD), DSA/FSAR, technical safety requirements (TSR)/technical specifications (TS), readiness review (RR)/startup plan, and Phase II agreement, as summarized in Table 3.

Table 3: Summary of Key Deliverables

Document	Timing	Purpose
NSDA	Milestone One: Early project phase	Defines regulatory engagement process, safety functions, codes, equivalencies, and key safety decisions.
PDSA (PSAR)/QAPD	Milestone Two: Preliminary design ~50%	Quality assurance program and preliminary integrated safety case: DOE approval provides regulatory certainty and minimizes risk for procurement.
DSA (FSAR)/TSR (TS)	Milestone Three: Final design	Final safety basis: DOE approval authorizes operation.
RR / Startup Plan	Milestone Four: Pre-operations	Verifies implementation of safety programs and readiness for nuclear operations.
Phase II Agreement	Milestone Five	Formally documents transition to commercial licensing at NRC, or other agreed upon scope.

Deliverable preparation, review, and approval support the identification, integration, and verification of safety requirements. The NSDA, including the Code of Record (COR), documents regulatory applicability and authorized equivalencies (e.g., NRC regulations, industry codes, etc.).

Deep Fission further elaborates and refines the COR and the fundamental safety functions identified in the NSDA in the PDSA/PSAR, DSA/FSAR, and TSR/TS. The QAPD includes configuration management (CM) to ensure integration and flowdown of safety requirements for design and operations. DOE approval of the NSDA, PDSA/PSAR, and DSA/FSAR via a safety evaluation report (SER) serves as formal verification of safety integration.

The RR confirms implementation of safety management programs prior to startup. After startup approval, the Joint Test Group (JTG) directs startup testing that, when successful, results in authorization to operate.

Finally, the Phase II agreement ensures a safe transition to commercial licensing by the NRC (or other agreed upon scope). The full power reactor used in the pilot is the same reactor Deep Fission will license through the NRC. That is, this pilot project will transition directly to NRC commercial oversight.

5.3 Regulatory Engagement Process

5.3.1 Regulatory Engagement Process Flow

Figure 4 portrays regulatory engagement process flow and swim lanes. Four horizontal swim lanes separate activities performed by SLT government and community, Deep Fission, DOE, and NRC. Five vertical columns segment the flow into phases: Agreements and alignment, preliminary design, final design, operation, and transition. Deep Fission's workflow in each phase, shown in the blue box, interacts frequently and transparently with DOE oversight activities. The edge of the green box bounding the Deep Fission and DOE swim lanes represents external touchpoints with SLT government and communities (at the top of the diagram), and with NRC (along the bottom).

The Deep Fission Team includes members primarily from three components: Licensing, Engineering, and Operations. Licensing serves as the lead Deep Fission organization for regulatory engagement. Acting as a trusted partner within Deep Fission and with federal and SLT regulating bodies, Licensing liaises, guides, and drives risk-informed, performance-based pathways for authorization, licensing, and operation. Engineering and its subcontractors design and implement the plant. Operations provides project and program management and quality assurance and operates the plant. The following subsections discuss the Deep Fission Team approach to engaging DOE, NRC, and SLT stakeholders.

5.3.1.1 Engagement with the DOE Review Team

Deep Fission engages with the DOE Review Team in the following activities orchestrated by representatives of Deep Fission Licensing:

- Meetings: Monthly status meetings and ad hoc meetings on critical issues.
- Internal design reviews: DOE Review Team invited to internal design reviews as observers.
- Community outreach: DOE may participate in community meetings and outreach with Deep Fission.
- Deliverables: Monthly reports and milestone documents, including comment resolution.

5.3.1.2 Engagement with NRC as Observers

Deep Fission Licensing may issue invitations for NRC Observer Team attendance and may provide submittals and meeting materials for awareness and advisory feedback.

5.3.1.3 Engagement with SLT Stakeholders and Communities

Deep Fission Licensing works with SLT stakeholders and communities to maintain open and consistent communications, secure necessary permits, coordinate emergency planning, establish agreements with the local jurisdiction for emergency response (e.g., fire and medical), and conduct public outreach and education.

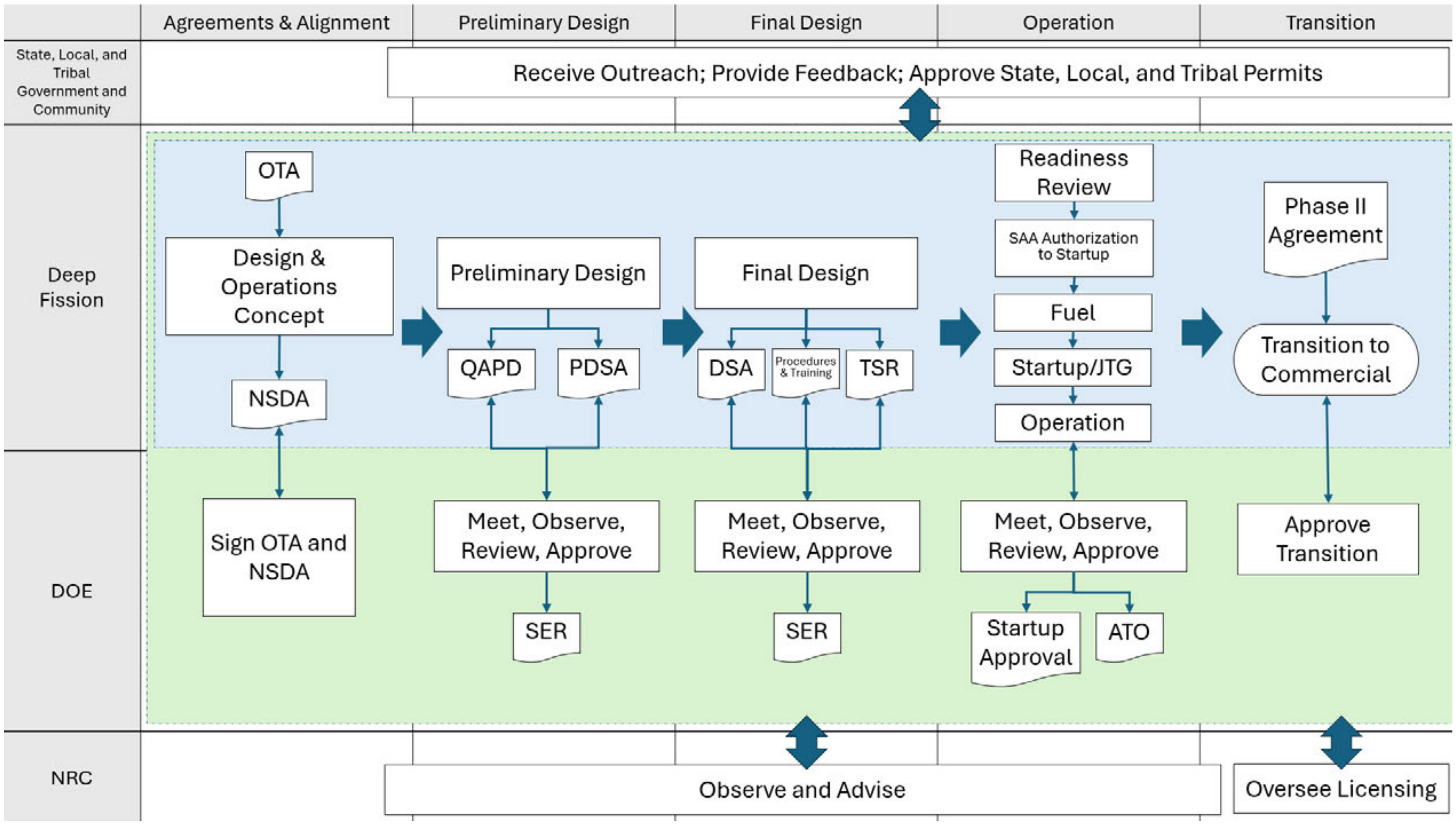


Figure 4: Regulatory Engagement Process Flow and Swim Lanes

5.3.2 Roles and Responsibilities

Deep Fission summarizes roles and responsibilities with a modified version of the traditional RASCI matrix. With the addition of a liaison role (i.e., L-RASCI), Deep Fission further clarifies roles and responsibilities for regulatory engagement:

L – Liaison: Acts as the primary point of contact for interorganizational interaction to foster relationships, facilitate collaboration and understanding, resolve issues, submit deliverables, coordinate schedules, and sponsor meetings.

R – Responsible: Performs the work.

A – Accountable: Approves the work.

S – Supportive: Helps the responsible team complete the work.

C – Consulted: Provides input.

I – Informed: Receives updates on progress or decisions.

Table 4 is the Deep Fission regulatory engagement L-RASCI matrix for an expanded set of project deliverables and tasks. As the Deep Fission lead for regulatory engagement, the Licensing Team acts as the liaison. Deep Fission Engineering is responsible for most of the deliverables other than project management, quality assurance, and facility operations, which are the responsibility of Deep Fission Operations. As the federal sponsor, DOE assumes the accountable role for deliverables and decision milestones in the pilot phase. DOE also plays supportive roles during meetings and is an informed observer at internal design reviews. NRC is an informed observer until after the pilot, whereupon it assumes the accountable role as the approval authority for commercial licensing. SLT governments and communities remain informed throughout the entire project. SLT governments also have approval authority for relevant permits.

Table 4: Deep Fission Regulatory Engagement L-RASCI Matrix for the Reactor Pilot Program

Deliverable/ Task Description	Deep Fission Licensing	Deep Fission Engineering	Deep Fission Operations	DOE	NRC	SLT Gov't & Community
Monthly and Ad hoc Meetings	L, R	S	S	S	I	
Monthly Reports	L, S	S	R	A	I	
Project Management Schedule	L, S	S	R	A	I	I
Milestone Reports	L, S	S	R	A	I	I
Special Status Reports	L, C	C	R	A		
NSDA	L, S	R	S	A	I	I
Internal Design Reviews	L, C	R	S	I	I	
Preliminary Design Package	L, C	R	S	A	I	I

Deliverable/ Task Description	Deep Fission Licensing	Deep Fission Engineering	Deep Fission Operations	DOE	NRC	SLT Gov't & Community
PDSA (PSAR)/QAPD	L, C	R	S	A	I	I
Final Design Package	L, C	R	S	A	I	I
DSA (FSAR)/TSR (TS)	L, C	R	S	A	I	I
Procedures and Training	L, C	S	R	A	I	I
Final Review Briefing Report	L, C	S	R	A	I	I
Startup Plan	L, C	R	S	A	I	I
Readiness Review	L, C	S	R	A	I	I
Initial Startup Testing/Joint Test Group	L, C	R	S	A	I	I
SLT Permits	L, C	R	S	I	I	A
NEPA Compliance	L, R	S	S	A	I	A
Community Outreach	L, R	S	S	A	I	I
Facility Operations	L, C	S	R	A	I	I
Transition to NRC	L, R	S	S	A	A	I

6 Key Safety Decisions for the Design

Deep Fission integrates Gravity Reactor technology with innovative subsurface safety concepts. Design decisions – from using qualified PWR fuel to relying on the protection provided by a deep borehole – reflect a commitment to safety through simplicity. Passive cooling, inherent pressure safety, borated chemistry control, and automated monitoring define reactor systems capable of maintaining safety without complex intervention. Deep Fission will demonstrate that deep borehole reactors can operate safely, securely, and predictably while relying on passive physics to ensure safety.

6.1 Safety Philosophy

Deep Fission designed the Gravity Reactor around a philosophy of inherent and passive safety. The reactor operates at relatively low power, creating a smaller radioactive source term than typical PWRs. By locating the reactor underground in a water-filled deep borehole, the design leverages the passive hydrostatic pressure safety in a geologically isolated subsurface environment. This setting eliminates the need for massive safety-related pressure retaining aboveground containment structures and provides stable conditions for the reactor. Deep Fission's safety strategy centers on the principle that geometry, depth, and natural forces maintain safety without relying on operator intervention or active systems. The column of water above and surrounding the reactor creates external hydrostatic pressure nominally equivalent to internal reactor pressure and essentially eliminates a rapid loss of coolant initiating event. This approach minimizes accident potential, reduces radiological consequences, and establishes a safe foundation for demonstrating borehole reactor feasibility.

Key safety features for the Deep Fission Gravity Reactor include:

- **Rely on the Water Column for Inherent Pressure Safety**
  The hydrostatic water column establishes a passive and stable pressure environment, preventing rapid depressurization events and obviating the need for a safety-related reactor coolant pressure boundary.
- **Rely on the Water Column for Inherent Cooling**
  The water column establishes a passive heat sink, removing decay heat and obviating the need for typical safety-related emergency core cooling systems.
- **Limit the Radiological Source Term**
  The reactor is small and low power, producing a smaller credible source term.
- **Operate Qualified PWR Fuel Well Below Design Limits**
  The design uses fully qualified PWR fuel under sub-limiting thermal-mechanical conditions. Fuel and cladding serve as the only safety-related SSCs, and the system maintains cladding integrity with high margin to prevent radionuclide release.
- **Maintain Strong Negative Reactivity Feedback**
  The selected fuel type provides well-characterized negative temperature coefficients, which inherently limit reactivity excursions and prevent conditions that could challenge cladding integrity.
- **Provide Large Time, Distance, and Shielding Separation**
  The deep geological configuration and mile of water ensure extensive spatial isolation and shielding between the reactor source term and the accessible environment, preventing credible radiological exposure pathways.
- **Scrub and Retain Radionuclides Within the Water Column**
  The water column continuously retains and scrubs radionuclides, further reducing any potential for radiological migration.
- **Ensure Slow and Predictable System Dynamics**
  The PCC system causes system conditions to evolve slowly, enabling operators to adjust or pause flow when required. Sources of rapid reactivity insertion are removed.
- **Verify Borehole Hydraulic Integrity Before Reactor Installation**
  The project team verifies borehole integrity prior to reactor emplacement, ensuring that under DBA conditions, the water inventory remains bounded with no credible mechanism for loss of the hydraulic column.
- **Implement Robust Borehole Sealing and Pressure-Retention Barriers**
  The design applies proven oil-and-gas-industry sealing technologies to establish multiple defense-in-depth barriers that prevent radionuclide migration.

- **Monitor the Single Credible Release Pathway**
  The system continuously monitors the borehole – the only credible egress path – to detect any abnormal conditions promptly and reliably.
- **Select Geology with Exceptional Stability**
  The siting process targets geologic formations with well-characterized properties and very low seismic hazard, thereby minimizing the potential for externally induced system perturbations. The act of drilling the borehole confirms geological conditions.

6.2 Proven PWR Design

The Gravity Reactor is an SMR that uses a light-water PWR design. It intentionally harnesses fundamental physical principles – such as natural circulation, Doppler broadening, and moderator density effects – to promote stable and inherently safe reactor operation. These mechanisms enable the use of passive safety systems and play a crucial role in enhancing the Gravity Reactor's resilience and operational simplicity.

6.3 Reactivity Control for Shutdown

The Gravity Reactor incorporates multiple independent and diverse means of reactivity control to ensure safe operation and shutdown under normal and off-normal conditions. Consistent with the established hierarchy of controls, the first means of reactivity control is passive and relies on fuel composition, enrichment, and core design to leverage the inherent, strong negative reactivity feedback. A second means of reactivity control is provided by the PCC system, which is an active system used to introduce measured quantities of soluble boron directly into the core. The PCC system provides operational reactivity control and shutdown.

In addition to soluble born injection by the PCC, the ARCS system provides the capability to inject an aqueous solution of high concentration soluble neutron absorber directly into the core to rapidly shut down reactivity. Finally, the borehole water volume is maintained with a concentration of soluble neutron absorber that will mix with the primary or secondary system coolant upon the breach of either boundary and passively shut down the core. Together, these multiple independent controls provide reliability, redundancy, and defense-in-depth for reactivity control and shutdown.

The Gravity Reactor's passive reactivity control works with temperature rise in two ways. As the reactor core temperature increases, Doppler broadening enhances neutron absorption in non-fissile material, immediately reducing reactivity. At the same time, the coolant becomes less dense, providing less moderation and further decreasing reactivity until subcriticality is reached. These feedback mechanisms operate continuously, without any need for operator action or electrical power. They inherently prevent the reactor from reaching prompt criticality and passively limit power excursions under both normal and off-normal conditions.

Operators use the PCC to control reactivity by adjusting boron concentration in the primary coolant. Using these adjustments, operators maintain desired levels of criticality during normal operation and insert sufficient negative reactivity during shutdown or transient conditions. The system injects borated coolant at a controlled rate that ensures safe shutdown even in the presence of credible equipment malfunctions or single failures. The ARCS uses a pressurized, near-core reservoir to provide a fixed rate of injection of an aqueous solution of soluble neutron absorber directly into the core upon indication of a transient. The system can also be used by the operator on demand.

In addition to the active systems, the borehole water mixed with soluble absorbers works passively to terminate reactivity transients. The negative reactivity insertion from the borehole water will permanently keep the reactor core subcritical following postulated accidents that mix primary coolant with water from the surrounding environment (e.g., pipe breaks).

The combination of inherent reactor feedback mechanisms, boron control using the PCC, rapid aqueous negative reactivity insertion with ARCS, and passive reactivity transient termination by borehole water mixed with soluble neutron absorbers provides multiple, diverse, and independent layers of reactivity control that support a robust defense-in-depth strategy. The passive and active design and safety features enable autonomous and self-regulating, as well as operator-controlled and automatic options, to respond to any transient. These systems rely on different physical principles and do not share common cause failure vulnerabilities.

6.4 Target Performance of SSCs

The Gravity Reactor's SSCs collectively protect workers, the public, and the environment during normal and off-normal conditions, ensuring sufficient safeguards with defense-in-depth capabilities. Implementing passive methods for reactor coolant pressure, confinement, reactivity control, natural circulation cooling, and geologic isolation provides multiple layers of defense and establishes a conservative and resilient safety posture suitable for this first-of-kind deep borehole reactor demonstration.

The Gravity Reactor confines radioactive materials within multiple passive barriers, including the fuel cladding, reactor canister, PP, PHX, borehole water, and BC. The reactor remains subcritical except during authorized, closely monitored tests, and it stays in a safe state during and following any anomaly, as supported by core design. It removes heat through passive primary loop natural circulation and convection mechanisms, with SP and the borehole water serving as long-term heat sinks. The design maintains radiation exposure below regulatory limits by geologically isolating the reactor within natural shielding. The combination of rock strata, borehole water, and BC and casing attenuates gamma and neutron surface-level radiation.

6.5 System Response to Normal Operations

Under normal conditions, the Gravity Reactor functions as designed. The system operates routinely in subcritical and critical states, with components performing within their intended parameters.

The reactor experiences two normal subcritical conditions:

- The reactor canister is empty of water
- The reactor canister is partially or completely filled with borated water.

When the reactor canister is above ground level, it remains dry in preparation for loading new fuel assemblies or with the new fuel assemblies already loaded. Administrative and design measures prevent unintentional addition of unborated water, maintaining the reactor in a safe subcritical state.

When lowering the reactor canister into and positioning it at the bottom of the borehole, operators fill the reactor canister with highly borated water. As operators prepare the system for approach to criticality, with the reactor in its operating position, they allow slow, controlled dilution of the reactor coolant boron concentration. The MC system continuously monitors reactor neutron flux, primary and secondary loop conditions, borehole water level, and PCC system parameters to ensure stable and safe progression toward criticality.

During normal reactor critical conditions, the system maintains steady operation. Changes to the system are slow and deliberate. There is a significant amount of time between a change made at the surface and a response at the reactor. Operators control boron concentration changes in small increments as specified in test procedures. The pressure is maintained in the secondary loop, while the MC system actively monitors neutron flux, primary and secondary coolant conditions, borehole water level, and PCC system performance. Through these coordinated actions, the system maintains controlled and stable operation under normal conditions.

6.6 System Response to Off-Normal Operations

Off-normal circumstances are evaluated from established PWR failure modes, borehole-specific risks (e.g., equipment emplacement failures), potential hazardous materials accidents, regional natural phenomena, and man-made external events. Examples of off-normal operations to be analyzed include:

- Breach of primary coolant boundary
- PHX tube break/leak
- Loss of heat removal capability
- Operator error during criticality approach
- Station blackout (loss of AC power)
- Dropped reactor canister during lowering
- Dropped fuel assembly at surface
- Mishandling of radioactive or chemical hazardous materials
- Natural phenomena (e.g., earthquake, tornado, flood, etc.)

- Man-made external events (e.g., plane crash, malicious acts and sabotage – physical and cyber)

Key safety decisions consider the context of reactor operations. Designed system responses leverage passive safety features, natural circulation, inherent negative fuel and moderator temperature coefficients of reactivity, and deep borehole containment.

6.7 Security of the Facility

Deep Fission incorporates a comprehensive, layered security strategy that combines passive engineering controls, administrative measures, and cyber and personnel protections.

The pilot site employs a defense-in-depth security posture centered on physical isolation, hardened barriers, and continuous monitoring. Once installed, the Gravity Reactor assembly rests deep below ground, making direct access physically impractical without specialized drilling equipment and a significant amount of time. The wellhead BC deters forced entry, vehicle impact, and severe weather events. [redacted] REDACTED MATERIAL [redacted] This passive design provides natural delay and deterrence comparable to fortified facilities.

RPP operates within a secure perimeter inside an industrial park. [redacted] REDACTED MATERIAL [redacted].

MC workstations connect to a separate, firewalled domain with tightly managed data transfer procedures. Network security protocols include intrusion detection, vulnerability management, access authorization, and incident response. These layered defenses ensure confidentiality, integrity, and availability of control systems and data associated with pilot operations.

Personnel receive specialized training in nuclear safety, cyber hygiene, and insider-threat awareness. Deep Fission ensures employees performing safety- or security-critical tasks meet ongoing behavioral and medical suitability requirements.

The pilot's facility security program integrates physical isolation, engineering barriers, cybersecurity controls, and personnel reliability measures into a cohesive protection framework. By combining deep geologic inaccessibility with standardized security and cyber-defense systems, Deep Fission achieves the equivalent of a hardened, actively guarded nuclear installation without a large protective force. This approach achieves adequate security while maintaining a lean, sustainable operational model.

6.8 Use of Qualified Fuel Types

A key safety design decision is to use established and qualified PWR fuel and operate it well within its performance limits. Deep Fission selected qualified LEU fuel and assemblies used globally by PWRs. This decision eliminates the need for new fuel certification, leveraging decades of operational data and regulatory precedent.

6.9 Monitoring Requirements and Operating Limits

The MC system continuously monitors neutron flux, primary and secondary loop pressures and temperatures, flow rates, and borehole conditions. The system automatically initiates shutdown if selected values exceed operating limits, such as neutron flux or temperature anomalies. System sensors measure radiation, chemistry, temperature, flow and pressure. These data streams enable operators to confirm operation within limits for temperature, pressure, boron concentration, and borehole water level, for example. Operators maintain strict control of PCC boron concentration before delivering borated water to the reactor.

6.10 Staffing and Operational Safety Management

During operations, on-site personnel include reactor operators, engineers, and technicians who oversee daily operations and testing. During post-operation monitoring, staffing levels decrease, increasing reliance on automated systems for data collection and borehole integrity checks. This staffing model ensures both safety and cost efficiency while maintaining operational standards.

7 Safety SSC Classification

When selecting controls that address a fundamental safety function, Deep Fission implements a strategy in the hierarchy of controls[c] recommended by DOE guidance. Specifically, the design of the Gravity Reactor:

- Minimizes hazardous material
- Prefers SSCs over administrative controls
- Prefers passive SSCs over active SSCs
- Prefers preventive controls over mitigative controls
- Prefers controls closest to the hazard because they may protect the largest population of potential receptors, including workers and the public
- Prefers controls effective for multiple hazards because they may use resources efficiently.

Although the project team does not anticipate deviations, it develops and explains the technical basis and supports any exception to this hierarchy, if necessary.

For the Gravity Reactor, all SSCs relied upon to prevent a DBA or mitigate its dose consequences such that they do not exceed the established evaluation guideline (EG)[d] (i.e., 5-25 rem total effective dose equivalent [TEDE]) are classified as "safety-related." SSCs that are not safety-related but still perform fundamental safety functions – and help to provide reasonable assurance that the reactor can be operated without undue risk to the health and safety of workers and the public – are classified as "important to safety." All safety-related SSCs are also important to safety. The use of the "safety-related" classification for the design

c. DOE-STD-1189-2016, "Integration of Safety into the Design Process"
d. Applying the 10 CFR 50.67 (b)(2)(iii) control room dose acceptance criteria of 5 rem TEDE to deterministic analyses of collocated worker dose consequences will eliminate the potential for challenging the EG.

of specified Gravity Reactor SSCs is informed by the definition set forth in 10 CFR Part 50.2, which is consistent with the definition of safety-class in 10 CFR Part 830. The use of "important to safety" aligns with the use of the same term as described in 10 CFR Part 50 Appendix A.

Taking into account the long operating history of PWR reactor designs, the extensive performance data available for SSCs used to control PWR hazards, and the passively safe features central to the design, the safety analysis process risk-informs the safety-related SSC classification as informed by 10 CFR Part 50.69 regulations. Specifically, the process implements the definitions of risk-informed safety classes (RISCs) when they are applicable and technically justifiable. The process detailed in RG 1.201, "Guidelines for Categorizing Structures, Systems, and Components in Nuclear Power Plants According to their Safety Significance," applies to support this implementation. Deep Fission may use a RISC-based approach for safety-related SSCs, supported by an appropriate level of risk evaluation.

Defense-in-Depth

Although the concept of defense-in-depth is often discussed in the context of nuclear safety, there is no single, consistent definition. Both the DOE and NRC have defined defense-in-depth in several different ways. A detailed, comprehensive study on the concept was performed by the NRC in 2016.[e] The study concluded that, despite the different definitions, there is general agreement that defense-in-depth is needed to compensate for uncertainties regarding reactor design and operation, the performance of its SSCs and operator actions, various natural phenomena, accident progression, as well as other parameters and events.

Defense-in-depth aims to address these uncertainties and ensure that the risk to public health and safety from operating the Gravity Reactor is acceptably low by preventing and mitigating postulated accidents. Accordingly, the design employs the following layers of protection, which reflect a defense-in-depth philosophy consistent with both the DOE approach[f] and the historical application of the concept for domestic power reactors described by the NRC:

Layer 1 – Prevention of Abnormal Operation and Failures

Accident prevention is the first priority. For the Gravity Reactor, this is accomplished by passively safe design and siting, as well as high-quality, construction, operations, and maintenance. In addition, design and operational provisions to prevent deviations of reactor state from well-known operating conditions will be used, as they are generally more effective and more predictable than measures aimed at mitigation of such departures.

The Gravity Reactor core will consist of commercially available LEU PWR fuel for which there is extensive operational history and transient response predictability. The core of the reactor will be designed to simplify and facilitate reactivity control.

Layer 2 – Control of Abnormal Operation and Detection of Failures

e. NUREG/KM-0009, "Historical Review and Observations of Defense-In-Depth"

f. The DOE approach to defense-in-depth is summarized in DOE Guide 420.1-1A, "Nonreactor Nuclear Safety Design Guide for use with DOE O 420.1C, Facility Safety."

For the Gravity Reactor, this is accomplished by normal control and indication systems, as well as other surveillance features. SSCs and administrative controls will be used to provide redundant and diverse control of the reactor and its operational state. Multiple means for detection will be used to monitor vital reactor processes and parameters (e.g., core neutron flux, temperature). Implementation of PDC will help to ensure that all SSCs important to safety are directly protective of the reactor's fundamental safety functions.

Layer 3 – Control of Accidents Within the Design Basis

A central component of defense-in-depth is minimization of the radioactive source term and the use of multiple, successive physical barriers for protection against the accidental release and transport of radioactivity and hazardous materials, where diverse and independent means are provided to accomplish safety functions.

The Gravity Reactor is designed to reduce the controls necessary to mitigate post-DBA dose consequences to acceptable levels. Primary control of postulated accident consequences is accomplished for the Gravity Reactor design by INP design features (e.g., geologic isolation within a borehole, hydrostatic water column above the reactor), which are both preventive and mitigative. In addition, passive and active engineered safety features (e.g., cladded solid oxide fuel, reactivity control systems), which are also capable of controlling transients, have been incorporated into the design.

The Gravity Reactor core is geologically isolated nominally one mile underground and immersed within a hydrostatic column of water at that depth. This passive barrier is redundant to the fuel matrix, fuel cladding, and canister that contains the reactor core. Together, the barriers are redundant and diverse and will work in succession to mitigate the transport of radionuclides. In addition, engineered systems for cooling and reactivity control will also contribute to this layer of protection by preventing and mitigating potential releases.

Layer 4 – Control of Severe Facility Conditions

This layer involves protection against severe accidents by controlling severe plant conditions and mitigating associated consequences that are beyond the design basis of the reactor. For the Gravity Reactor, this control is accomplished through the passive features of its design, which will not allow an initiating event to progress beyond the design basis of the reactor. Features inherent to the operation of a PWR design (e.g., negative coolant/moderator temperature coefficient) will provide this protection. In addition, the same passive and engineered features discussed in Layer 3 will also effectively mitigate radionuclide releases resulting from even more severe postulated conditions. Finally, emergency preparedness procedures and processes will also be in place to further mitigate and protect against severe accident consequences.

Layer 5 – Mitigation of Radiological Consequences Beyond the Design Basis

Anticipatory emergency planning and response procedures will be employed to further mitigate dose consequences in the unlikely event of a post-accident release of radionuclides. As necessary for emergency response, means will be provided to monitor accident releases.

Additionally, emergency management planning provides a mechanism for taking appropriate actions to protect the public and workers in the highly unlikely event that all other barriers fail. In establishing appropriate emergency response planning, applicable requirements will be met.

8 Authority to Confirm and Make Safety Decisions

At Deep Fission, clearly defined authority ensures qualified leaders and personnel make informed safety and quality decisions at every level of the organization in accordance with a graded approach philosophy and company procedures.

The Chief Executive Officer (CEO) holds overall authority for quality and safety. The CEO defines quality and safety policy, allocates resources, and ensures the Health, Safety, & Quality (HS&Q) organization operates independently and effectively. The CEO maintains unrestricted access to findings and serves as the final authority in resolving quality and safety issues.

The HS&Q Manager administers the Quality Assurance Program and exercises the authority to identify conditions adverse to quality, recommend and verify corrective actions, and stop work when necessary to protect safety or quality. The HS&Q Manager leads audits, surveillances, and management assessments, and verifies personnel meet qualification requirements. This role carries unrestricted access to facilities, personnel, and records relevant to quality and safety performance.

Serving as the Design Authority, the Chief Nuclear Officer (CNO) ensures the technical basis, adequacy, and configuration of safety-related and mission-significant designs. The CNO may delegate design authority to qualified subordinates or suppliers; however, Deep Fission retains full accountability for design integrity. Engineering performs design changes, including field modifications, temporary alterations, and software revisions in accordance with configuration control and quality requirements and procedures. Each change is evaluated for its impact on safety, performance, and regulatory commitments before implementation. Formal design reviews at key milestones confirm design outputs meet requirements, verification activities are complete, and open actions are resolved. Deep Fission obtains permits from local jurisdictions, when necessary and appropriate.

Engineers perform design work in accordance with approved procedures and established requirements. Deep Fission retains ultimate responsibility for the adequacy and safety of designs incorporated into its projects.

The responsibility of the Design Authority does not include approving exemptions or equivalencies to OTA requirements. Deep Fission submits requests for exemptions and equivalencies to the SBAA, or possibly the local jurisdiction, depending on the nature of the request.

The Chief Operating Officer (COO) directs operational planning, construction, and testing activities. The COO ensures personnel follow approved procedures, drawings, and inspection plans, and quality assurance hold points receive full observance. Working with the HS&Q Manager, the COO promotes a culture that prioritizes quality and safety over schedule or cost.

All Deep Fission employees and contractors hold the authority and responsibility to suspend work if continuation could compromise quality or safety performance. The HS&Q Manager and quality assurance personnel hold explicit authority to issue stop-work directives. Work resumes only after responsible personnel correct and verify the condition.

Deep Fission fosters organizational freedom and open communication. Any employee may report quality or safety concerns directly to their supervisor, HS&Q Manager or CEO without fear of reprisal. Management assessments and internal audits periodically verify the HS&Q organization maintains its independence and objectivity.

9 Dose Consequence

The Gravity Reactor leverages passive, natural phenomena for both control and operation of the reactor, as well as to prevent and mitigate accidental releases of radiological material. For example, the operational pressure for the Gravity Reactor is achieved passively, as result of its siting beneath a hydrostatic column of water that is nominally one mile tall. With careful design considerations, this water volume and the pressure it provides make it not credible to result in a loss of coolant. In addition, geological isolation and the depth of submergence in water provide unique conditions and passively mitigative features that scrub, delay, and remove radionuclides postulated to be released and transported to the surface. As the design matures, the safety analysis will refine the analytical credit taken for these features in the safety analysis and determination of potential dose consequences.

For the purpose of this NSDA, Deep Fission deterministically estimated the dose consequence resulting from a credible MHA scenario consistent with requirements of 10 CFR Part 50.67 and guided by the alternative source term (AST) methodology of RG 1.183. The guidance of RG 1.183 is applicable to the PWR design of the Gravity Reactor, which uses conventional PWR fuel and operates nominally at the same temperatures and pressures. Conservatively, this MHA estimation non-mechanistically assumes that, while operating at its maximum rated power (19.5 MWt) near the end of its cycle life (cycle length of 1095 effective full power days), a rupture of all core assembly fuel rods occurs. As designed for the Gravity Reactor, the radiological consequences of this postulated accident to workers and the public would not be exceeded by any other credible accident that could occur during the operational lifetime of the reactor.

In this MHA scenario, all dose significant radionuclides are assumed to be maximized, and following this event, all radionuclides present in the gas gap and plenum of the fuel become available for transport to dose receptors. The subsequent release of these available radionuclides is assumed to progress in fractions and with timing that aligns with the alternative source term (AST) guidance for a PWR core (i.e., RG 1.183). The conventional PWR fuel implemented in the core helps to ensure the radionuclide release is consistent with the AST. For this MHA dose consequence estimation, no credit is taken for any engineered safety feature or SSC to mitigate releases, and only INP design features of the plant are relied on to constrain resulting dose consequences.

For this estimation, any radionuclide that reaches the surface is available for inhalation, ingestion, and direct dose by all modeled dose receptors. Deep Fission assumes that the dose to the co-located worker location of 100 m from a release, per DOE guidance in DOE-STD-3009-2014, will bound any dose to the workers and the public. Without site-specific meteorological data yet available, the analysis uses a very conservative atmospheric dispersion coefficient (χ/Q) of 3.5 x 10^{-3} s/m^3 consistent with the guidance of DOE-STD-3009-2014 when addressing the co-located worker dose receptor.

The resulting bounding estimated dose to the collocated worker following the postulated MHA is less than 5 rem TEDE (i.e., < 5 rem TEDE).

10 Natural Phenomena Hazard Design Categorization

In accordance with NE-STD-1020-2025, Deep Fission establishes NDCs for safety-related SSCs by evaluating the unmitigated consequences of SSC failure. For Government-Owned, Contractor-Operated (GOCO) and Government-Owned, Government-Operated (GOGO) facilities, NE-STD-1020-2025 provides the following NDC definitions:

- NDC-1 for SSCs whose failure results in unmitigated dose consequences of less than 5 rem TEDE to a co-located worker.
- NDC-2 for SSCs whose failure results in unmitigated dose consequences of between 5 and 100 rem TEDE to a co-located worker and less than between 5 and 25 rem TEDE to the public.
- NDC-3 for SSCs whose failure results in unmitigated dose consequences of greater than 100 rem TEDE to a co-located worker and greater than 25 rem TEDE to the public.

However, for privately funded DOE-authorized facilities, the co-located worker dose consequence criteria for NDC category classification does not apply. Nevertheless, the preliminary bounding dose analysis for the postulated MHA shows that neither the co-located worker nor the public would receive unmitigated dose consequences up to 5 rem TEDE.

The MHA/MCA analysis appropriately bounds the spectrum of credible DBAs, crediting only on INP design features (e.g., 1-mile hydrostatic column of water). Therefore, based on this result, Deep Fission does not anticipate identifying any SSC in the DSA for the Gravity Reactor that will be required to perform its safety function during a design basis natural phenomena hazard (NPH) event for protection of the public and/or co-located workers.

The Gravity Reactor design and associated safety analysis continues to mature. Therefore, if Deep Fission determines the need for safety-related SSCs to mitigate design basis NPH accidents, the appropriate NPH category will be assigned to the identified SSCs, in accordance with NE-STD-1020-2025. This categorization will be supported by the dose consequence analysis of the applicable NPH-initiated DBA (i.e., seismic, wind, flood, precipitation, and volcanic).

11 Code of Record – Applicability and Equivalencies

The COR is a list of codes, standards, and regulatory requirements determined by Deep Fission to be applicable to the design. It establishes the governing technical framework under which Deep Fission develops, reviews, and approves the design. The COR provides traceability and ensures the design remains in conformance with applicable industry, national, and DOE standards throughout the project life cycle.

Deep Fission may determine that an alternative approach provides safety or performance equal to or better than that prescribed by a generally applicable code or standard. In such a case, the COR documents the exception and references the supporting technical evaluation. The technical evaluation demonstrates the alternative approach maintains or enhances safety relative to the applicable requirement. The technical evaluation also includes approval from the local jurisdiction for an exemption or equivalency for which the local jurisdiction has approval authority.

Detailing the applicability of industry codes and standards to the design, Deep Fission developed the initial COR (see Appendix A) in support of this NSDA and maintains it as a key reference in both the PDSA/PSAR and DSA/FSAR development cycles. Deep Fission elaborates and updates the COR throughout the design process, discusses potential exemptions or equivalencies with DOE, places it under configuration control at the preliminary design phase to ensure consistency with the final authorized design, and submits it to DOE for review and approval with each safety basis submittal. DOE approval of the safety basis deliverables signifies concurrence with the COR and with any associated exemptions or equivalencies referenced by Deep Fission.

12 Engineering Process and Requirement Flowdown

Deep Fission is implementing a structured systems engineering process to manage technical requirements from their initial definition through verification, DOE authorization, and establishment of the operational baseline.

Deep Fission's engineering process leverages the system engineering framework, best practices, and guiding principles described in ASME PSD-1. Deep Fission uses PSD-1 as a guideline for integrating requirement identification, allocation, verification, and validation into a disciplined, configuration-controlled process. PSD-1 aligns well with the needs for the Gravity Reactor as the standard focuses on first-of-a-kind plant designs. Deep Fission employs traditional yet agile and iterative design processes to systematically address and resolve many unknowns as the design matures from abstract concepts to real-world physical implementation.

The engineering process spans three primary design phases – Initial, Preliminary, and Detailed Design – corresponding to the establishment of the site/project, system/structure, and component baselines, respectively. Each baseline defines the approved configuration of design information. The site/project baseline captures top-level requirements and early design concepts; the system/structure baseline refines and decomposes those requirements into system-level specifications; and the component baseline establishes detailed "build-to" specifications and test requirements. Deep Fission maintains baselines within the project's CM system and links them to the OTA contract requirements and DOE authorization basis documentation.

Deep Fission manages technical requirements through a controlled requirements management (RM) process that provides complete traceability from DOE contract and other top-level requirements down to individual components.

Verification and validation activities provide evidence that the design satisfies technical and regulatory requirements.

CM ensures approved design information remains accurate, consistent, and traceable throughout the project life cycle. Deep Fission establishes each technical baseline under formal configuration control. Deep Fission follows NRC 10 CFR Part 50.59, which permits changes to facilities, procedures, or tests without prior regulatory approval, provided those changes do not create an unreviewed safety question or exceed established safety limits.

Deep Fission maintains records supporting RM and CM in accordance with 10 CFR 830 Subpart A and NE Order 414.1.

Through this disciplined engineering process, Deep Fission ensures traceable requirements, verifiable design decisions, and transparent changes. This structured, systems-based approach provides DOE with confidence that the design meets its safety, regulatory, and performance objectives, and the final operational baseline represents a verified, authorized configuration.

13 Fire Hazards Analysis and Fire Protection Program

Deep Fission will develop and maintain a fire hazards analysis (FHA) and a fire protection program (FPP). Preliminary versions of the FHA and FPP provide input for the PDSA and the overall safety basis development process for the RPP consistent with the requirements and outcome objectives of NE Order 420.1, "Facility Safety" and DOE-STD-1066-2023, "Fire Protection Design Criteria." The preliminary FHA identifies and evaluates facility fire hazards, combustible inventories, ignition sources, fire-induced initiating events, and the potential effects of fire on workers, the public, and SSCs important to safety and defense-in-depth. The FPP addresses fire protection requirements and implementation applicable to facility design, operations, emergency response, fire hazards analysis and assessments, wildland fire considerations, and other fire protection elements. Both the FHA and the FPP are living documents that Deep Fission update as the design progresses. Deep Fission will include drafts of the FHA and FPP as supplements to the PDSA.

14 Principal Design Criteria

Deep Fission's identification of PDC is still in progress. Deep Fission will include the PDC in the PDSA. The PDC development process is conducted in three tasks. In the first task, each fundamental safety function is mapped to its closest analog within the GDC family of 10 CFR Part 50, Appendix A. The mapping is informed by the crosswalk methodology of RG 1.232, "Guidance for Developing Principal Design Criteria for Non-Light Water Reactors," which, although developed for non-LWR applicants, provides a structured methodology for translating between the GDC and design-specific criteria. In the second task, the analyst considers the role of the credited INP design features and of each engineered SSC family that contributes to the corresponding safety function. The role of the INP design feature is captured as a design feature constraint (in the sense of NUREG-1431, Section 4.0) and the role of the engineered SSC is captured as one or more performance-based PDCs. In the third task, each PDC is reviewed for completeness against the seven GDC categories of 10 CFR Part 50, Appendix A (overall requirements; multiple fission product barriers; protection and reactivity control systems; fluid systems; reactor containment; fuel and reactivity control; control of releases of radioactive materials), to confirm that no fundamental safety function category has been overlooked. Where the GDC addresses a feature that is precluded by Gravity Reactor design — for example, those addressing aspects of large pressure-suppression containments that have no analog in the borehole-emplaced configuration, the absence of a PDC is documented with a brief explanation of the technical basis.

15 References

Federal Regulations

- 10 CFR Part 50, “Domestic Licensing of Production and Utilization Facilities”
- 10 CFR Part 52, “Licenses, Certifications, and Approvals for Nuclear Power Plants”
- 10 CFR Part 830, “Nuclear Safety Management”
- 10 CFR Part 835, “Occupational Radiation Protection”
- 10 CFR Part 1004, “Freedom of Information Act (FOIA)”
- 5 U.S.C. § 552(b)(4) – FOIA Exemption 4

DOE Orders, Standards, and Handbooks

- DOE Guide 420.1-1A, “Nonreactor Nuclear Safety Design Guide for use with DOE O 420.1C, Facility Safety”
- DOE Guide 423.1-1B, “Implementation Guide for Use in Developing Technical Safety Requirements”
- DOE-HDBK-1163-2020, “Integration of Hazard Analyses”
- DOE-HDBK-1224-2024, “Hazard and Accident Analysis Handbook”
- DOE-STD-1189-2016, “Integration of Safety into the Design Process”
- DOE-STD-1271-2025, “Authorization Pathway for Nuclear Facilities”
- DOE-STD-3009-2014, “Preparation of Nonreactor Nuclear Facility Documented Safety Analysis”
- NE Order 414.1, “Quality Assurance”
- NE Order 420.1, “Facility Safety”
- NE-STD-1020-2025, “Natural Phenomena Hazards Analysis and Design Criteria for DOE Facilities”
- NE-STD-1027-2025, “Hazard Categorization of DOE Nuclear Facilities”

NRC Regulatory Guides

- DG-1414, “Alternative Evaluation for Risk Insights (AERI) Framework”

- RG 1.70, “Standard Format and Content of Safety Analysis Reports for Nuclear Power Plants (LWR Edition)”
- RG 1.183, “Alternative Radiological Source Terms for Evaluating Design Basis Accidents at Nuclear Power Reactors”
- RG 1.201, “Guidelines for Categorizing Structures, Systems, and Components in Nuclear Power Plants According to their Safety Significance”
- RG 1.206, “Applications for Nuclear Power Plants”
- RG 1.233, “Guidance for a Technology-Inclusive, Risk-Informed, and Performance-Based Methodology to Inform the Licensing Basis and Content of Applications for Licenses, Certifications, and Approvals for Non-Light-Water Reactors”
- RG 1.253, “Guidance for Technology-Inclusive Content-of-Application Methodology to Inform the Licensing Basis and Content of Applications for Licenses, Certifications, and Approvals for Non-Light-Water Reactors”

<u>NRC Standards, NUREGs, and Guidance Documents</u>

- NUREG-0800, “Standard Review Plan (SRP) for the Review of Safety Analysis Reports for Nuclear Power Plants,” Chapter 15
- NUREG/KM-0009, “Historical Review and Observations of Defense-in-Depth”

<u>Industry Standards and Guidance</u>

- ASME PSD-1, “Integrating Systems Engineering and Plant Design,” October 2025
- IEEE-379-2014, “Standard for Application of Single-Failure Criterion to Nuclear Power Generating Station Safety Systems”
- NEI 18-04, “Risk-Informed Performance-Based Technology-Inclusive Guidance for Advanced Reactor Licensing Basis Development”

A. Appendix A – Code of Record

A.1 Introduction

Qualifying Statement for the NSDA Code of Record

The COR included with this NSDA is preliminary in nature and is provided for early visibility into the industry codes, standards, DOE requirements, and other design basis documents currently identified as potentially applicable to this project. Consistent with DOE expectations for the NSDA phase, the COR presented here does not represent a final or complete listing of all required standards. Deep Fission will identify additional applicable requirements as the design matures and will update the COR accordingly.

At this phase, the project team recognizes that code variances, equivalencies, and exemptions may be needed, but many of these are not yet known. As the project advances into preliminary and final design, Deep Fission will evaluate the need for such variances, equivalencies, or exemptions in greater detail. The project team will provide technical justification demonstrating that any proposed deviations and alternative approaches meet or exceed the safety intent of the referenced code or standard, in accordance with DOE requirements.

Inclusion of a standard in this preliminary COR does not imply that Deep Fission will follow all requirements within that standard. Deep Fission intends to apply the relevant and applicable portions of the listed standards as part of a graded approach to project design, development, implementation, and closeout. Deep Fission will apply standards commensurate with:

1. The relative importance to safety, safeguards, and security
2. The magnitude of any hazard involved
3. The life cycle stage of the facility
4. The programmatic mission of the facility
5. The particular characteristics of the facility and its systems
6. The relative importance of radiological and non-radiological hazards
7. Any other relevant factor necessary to ensure appropriate and defensible application of requirements.

As the design progresses, Deep Fission will place the COR under configuration control beginning at preliminary design, updating it to reflect the incorporation of more detailed and project-specific requirements. Deep Fission will formally maintain the COR through final design, construction, operation, and eventual decommissioning. DOE review and approval of safety design deliverables at each phase will signify DOE concurrence with the evolving COR, including any documented exemptions, equivalencies, or alternative approaches.

A.2 Purpose

This COR document establishes the controlled set of laws, regulations, consensus codes and standards that guide the design and testing of the RPP test reactor. The absence of a law, regulation, or consensus code or standard does not indicate that it does not apply. Deep Fission anticipates updating the COR as the project design evolves.

This appendix also provides references to directives to be considered for programmatic activities, such as project programs and workflows. This COR includes regulatory guidance information relevant to the RPP design.

A.3 Scope

This COR applies to the design and characteristics of facilities and SSCs of the RPP. The specific codes and standards that apply to the design development of individual plant systems will be determined during the design process when the applicable requirements for each system are developed.

A.4 Sources

This COR extracts the list of required laws, regulations, codes, and standards including the following sources:

- Conformed contract technical requirements
- Federal, State, and local regulations, standards and codes
- Approved documented commitments made to regulators, customers, and other stakeholders
- Selection of consensus codes and standards by RPP personnel.

A.5 Requirement of Design Documents

Deep Fission will use the contents of this COR to develop facility and SSC requirements and design including:

- Discipline-specific design criteria
- Facility specifications
- Systems specifications
- Structure specifications
- Procurement specifications
- Component data sheets
- Design drawings
- System design descriptions.

A.6 Regulations

A.6.1 U.S Federal Regulations

Identification	Name	Version to Use
10 CFR Part 830	Nuclear Safety Management (Subpart A & B)	
10 CFR Part 835	Occupational Radiation Protection	
10 CFR Part 851	Worker Safety and Health Program	
29 CFR 1910	Occupational Safety and Health Standards	
29 CFR 1926	Safety and Health Regulations for Construction	
40 CFR 61, Subpart H	National Emissions Standards for Emissions of Radionuclides Other Than Radon from Department of Energy Facilities	
10 CFR Part 1021	DOE National Environmental Policy Act Implementing Procedures,	
40 CFR Parts 1500–1508	Council on Environmental Quality Regulations for Implementing NEPA, as amended	
48 CFR 970,5223-1	Integration of Environment, Safety, and Health into Work Planning and Execution	
40 CFR Part 141	National Primary Drinking Water Regulations,	
40 CFR Part 124	Procedures for Decision-making (Permitting),	
40 CFR Parts 51 and 58	State Implementation Plans and Ambient Air Quality Monitoring Requirements	
40 CFR 51.166	Prevention of Significant Deterioration,	
40 CFR Part 60	New Source Performance Standards,	
40 CFR Parts 61 and 63	National Emission Standards for Hazardous Air Pollutants,	
40 CFR Parts 239–273	RCRA Implementing Regulations	
40 CFR Parts 700–799	Toxic Substances Control Act, 15 USC 2601 et seq.;	
10 CFR Part 820	Procedural Rules for DOE Nuclear Activities,	
40 CFR Part 68	Chemical Accident Prevention Provisions,	
40 CFR Part 191	Environmental Radiation Protection Standards	
40 CFR Parts 355, 370, 372	Emergency Planning and Community Right-to-Know Act (EPCRA), 42 USC 11001 et seq.	
10 CFR Part 140	Financial Protection Requirements (Price-Anderson Act implementation)	
40 CFR Part 112	Oil Pollution Prevention,	

A.6.2 U.S. Department of Energy (DOE) Standards

Number	Name	Version to Use
DOE-STD-1098-2017	Radiological Control	2017
NE-STD-1020-2025	Natural Phenomena Hazard Analysis and Design Criteria for DOE Facilities	Change Notice 1
NE-STD-1027-2025	Hazard Categorization of DOE Nuclear Facilities	2025
DOE-STD-1066-2023	Fire Protection	2023
DOE-STD-1073-2016	Configuration Management	2016
DOE-STD-1104-2016	Review & Approval of Nuclear Facility Safety Basis and Safety Design Basis Documents	2016
DOE-STD-1237-2021	Documented Safety Analysis for DOE Reactor Facilities	2021
DOE-STD-1269-2022	Air Cleaning Systems in DOE Nuclear Facilities	2022
DOE-STD-1271-2025	Authorization Pathway for Nuclear Facilities	2025

A.6.3 State of Kansas Regulations

Identification	Name	Version to Use
K.S.A. 65-3001 et seq.; K.A.R. 28-19 et seq.	Kansas Air Quality Act & Regulations	
K.S.A. 65-161 et seq.; K.A.R. 28-16 et seq.	Kansas Water Pollution Control Act & Wastewater Permitting	
KDHE Construction Stormwater General Permit	Stormwater Discharge (NPDES)	
K.S.A. 65-171d et seq.; K.A.R. 28-46 et seq.	Underground Injection Control (UIC)	
K.S.A. 65-3430 et seq.; K.A.R. 28-31	Hazardous Waste (RCRA)	
K.S.A. 65-3401 et seq.; K.A.R. 28-29	Solid Waste Management	
K.S.A. 65-34,100 et seq.; K.A.R. 28-44	Storage Tank Act	

Identification	Name	Version to Use
K.S.A. 55-150 et seq.; K.A.R. 82-3-100 et seq.	Oil & Gas / Well Permitting	
K.A.R. 82-3-106 – 120	Drilling, Casing, Cementing	
K.S.A. 55-162; K.A.R. 82-3-119	Logging & Reporting	
K.S.A. 65-34,161 et seq.; K.A.R. 28-71	Voluntary Cleanup Program	
K.S.A. 65-5701 et seq.	Tier II Reporting	
K.S.A. 66-1,129 et seq.	Hazardous Materials Transportation	
K.A.R. 36-1-1 et seq.	Oversize / Overweight Permits	
KCC Induced Seismicity Guidelines	Seismic Monitoring & Response	2014-present

A.6.4 Municipal Codes

Identification	Name	Version to Use
Labette County Ordinances (adopted under K.S.A. 65-3410 et seq.)	Environmental Health / Sanitation Regulations	
Labette County Floodplain Ordinance (adopted under K.S.A. 12-766; 44 CFR 60)	Flood Damage Prevention	
Labette County Emergency Management Program (K.S.A. 48-928 et seq.)	Emergency Operations & LEPC Coordination	
Locally Adopted Fire Code (per K.S.A. 31-133)	Fire Protection Regulations	
Labette County Ordinances (adopted under K.S.A. 65-3410 et seq.)	Environmental Health / Sanitation Regulations	

A.7 U.S. DOE Directives

These directives are programmatic in nature and do not specify technical requirements regarding facilities, systems, structures, or components.

Identification	Name	Version to Use
NE O 151.1	Comprehensive Emergency Management System	2025
NE O 225.1	Accident Investigations	August 2025
NE O 226.1	Implementation of DOE Oversight Policy	2025
NE P 226.2	Policy for Federal Oversight and Contractor Assurance Systems	
NE O 227.1	Independent Oversight Program	
NE O 231.1	Environment, Safety and Health Reporting	Admin chg. 1
NE O 232.2	Occurrence Reporting And Processing Of Operations Information	Minor chg. 1
DOE O 413.3B	Program and Project Management for the Acquisition of Capital Assets	Change Notice 7, 2023
NE O 414.1	Quality Assurance	2025
NE O 420.1	Facility Safety	Chg. 1 (LtdChg), 2026
NE O 422.1	Conduct of Operations	
NE O 425.1	Verification of Readiness to Startup or Restart Hazard Category 1 and 2 Nuclear Facilities	Minor chg. 1
NE O 426.2	Personnel Selection, Training, Qualification, and Certification Requirements for DOE Nuclear Facilities	2025
NE O 433.1	Maintenance Management Program for DOE Nuclear Facilities	2025
NE O 435.1	Radioactive Waste Management	2025
DOE M 441.1-1	Nuclear Material Packaging	Change Notice 1
DOE O 442.2	Differing Professional Opinions for Technical Issues Involving Environmental, Safety, and Health Technical Concerns	2011
DOE O 442.1B	Department of Energy Employee Concerns Program (No alternative requirements are allowed.)	2019
NE O 458.1A	Radiation Protection of the Public and the Environment	
DOE O 460.1D	Hazardous Materials Packaging and Transportation Safety	Change Notice 1
DOE O 460.2B	Departmental Materials Transportation Management	

Identification	Name	Version to Use
DOE O 461.2	Onsite Packaging and Transfer of Materials of National Security Interest	
DOE O 461.1C	Packaging and Transportation for Offsite Shipment of Materials of National Security Interest	Change Notice 1
NE O 470.1	Office of Nuclear Energy Safeguards and Security	
DOE O 471.6	Information Security	Change Notice 4
DOE O 471.7	Controlled Unclassified Information	
DOE O 471.1B	Identification and Protection of Unclassified Controlled Nuclear Information	
DOE O 475.1	Counterintelligence Program	
DOE O 475.2B	Identifying Classified Information	
DOE O 486.1A	Foreign Government Sponsored or Affiliated Activities	

A.8 Design Code of Record

A.8.1 General Design

Identification	Name	Version to Use
AISC 325-23	Steel Construction Manual	15th edition
AISC 360-22	Specification for Structural Steel Buildings	2022
ASCE 7	Minimum Design Loads and Associated Criteria for Buildings and Other Structures	2023
AWS D1.1/D1.1M	Structural Welding Code - Steel	2025
ASME NQA-1	Quality Assurance Requirements for Nuclear Facility Applications	2019
ICC IBC	International Building Code	2024
NFPA 101	Life Safety Code	
ASME BPVC Section VIII.1	Boiler and Pressure Vessel Code, Rules for Construction of Pressure Vessels Division 1	2025
ASME BPVC Section VIII.2	Rules for Construction of Pressure Vessels Division 2-Alternative Rules	2025
ASME Section XI	Rules for Inservice Inspection of Nuclear Reactor Facility Components, Division 1, Rules for Inservice Inspection of Nuclear Power Plant Components	2025

Identification	Name	Version to Use
WRC Bulletin 297	Local Stresses in Cylindrical Shells Due to External Loadings on Nozzles- Supplement to WRC Bulletin No. 107	1984
WRC Bulletin 537	Precision Equations and Enhanced Diagrams for Local Stresses in Spherical and Cylindrical Shells Due to External Loadings for Implementation of WRC Bulletin 107	2022
API RP 96	Deepwater Well Design and Construction	2013
API RP 10B-3	Testing of Well Cements Used in Deepwater Well Construction	2nd Edition
API SPEC 10A	Cements and Materials for Well Cementing	25th Edition
ANS 8.17	Criticality Safety Criteria for the Handling, Storage, and Transportation of LWR Fuel Outside Reactors	2004 (R2024)
ANS 40.37	Mobile Low-Level Radioactive Waste Processing Systems	2009 (R2016)
ANS 55.1	Solid Radioactive Waste Processing System for Light-Water-Cooled Reactor Plants	2021
ANS 55.4	Gaseous Radioactive Waste Processing Systems for Light-Water Reactor Plants	1993 (R2007)(W2017)
ANS 55.6	Liquid Radioactive Waste Processing System for Light-Water Reactor Plants	1993 (R2007)(W2017)

A.8.2 Civil, Structural, and Architectural

Identification	Name	Version to Use
ACI-370R-14	Report for the Design of Concrete Structures for Blast Effects	2014
ACI CODE-318-25	Building Code for Structural Concrete- Code Requirements and Commentary	2025
AISC A341-22W	Seismic Provisions for Structural Steel Buildings	2022
AISC A358-22	Prequalified Connections for Special and Intermediate Steel Moment Frames for Seismic Applications	2022
ASCE 4	Seismic Analysis of Safety-Related Nuclear Structures	2016
ASCE 43-19	Seismic Design Criteria for Structures, Systems, and Components in Nuclear Facilities	2021

Identification	Name	Version to Use
AWS A2.4	Standard Symbols for Welding, Brazing, and Nondestructive Examination	2020
AWS D1.2/D1.2M	Structural Welding Code - Aluminum	2014
AWS D1.3/D1.3M	Structural Welding Code - Sheet Steel	2018
AWS D1.4/D1.4M	Structural Welding Code - Steel Reinforcing Bars	2018
AWS D1.8/D1.8M	Structural Welding Code – Seismic Supplement	2025

A.8.3 Mechanical

Piping

Identification	Name	Version to Use
API RP 5A3	Thread Compounds for Casing, Tubing, Line Pipe, and Drill Stem Elements	4th Edition
API RP 5B1	Gauging and Inspection of Casing, Tubing, and Line Pipe Threads	5th Edition
API RP 5C1	Recommended Practice for Care and Use of Casing and Tubing	18th Edition
API RP 5C3	Calculating Performance Properties of Pipe Used as Casing or Tubing	8th Edition
API SPEC 5L	Line Pipe	46th Edition
API SPEC 5CT	Casing and Tubing	11th Edition
ASME B31.3	Process Piping	2024
ASME A13.1	Scheme for Identification of Piping Systems	2015
ASME B16.5	Pipe Flanges and Flanged Fittings	2020 Edition
ASME B31.1	Power Piping	2024
ASME B31.9	Building Services Piping	2020 Edition
API RP 17B	Recommended Practice for Flexible Pipe	6th Edition

Potable Water and Sewer

N/A

Heating, Ventilating, and Air Conditioning and Ducting

N/A

Hoisting and Rigging

Identification	Name	Version to Use
ASME B30.9	Slings	2010 Edition
ASME B30.10	Hooks	2009 Edition
ASME B30.11	Monorails and Underhung Cranes	2010 Edition
ASME B30.20	Below the Hook Lifting Devices	2013 Edition
ASME B30.26	Rigging Hardware	2010 Edition

A.8.4 Wellhead and Downhole Equipment

Identification	Name	Version to Use
API RP 14B	Design, Installation, Operaton, Test, and Redress of Subsurface Safety Valve Systems	6th Edition
API RP 17A	Design and Operation of Subsea Production Systems	6th Edition
API STD 53	Well Control Equipment Systems for Drilling Wells	5th Edition
API TR 6AF	Technical Report on Capabilities of API Flanges Under Combinations of Load	6th Edition
API BULL 6J	Bulletin on Testing of Oilfield Elastomers	1992
API SPEC 6A	Specification for Wellhead and Tree Equipment	21st Edition
API SPEC 6D	Specification for Valves	25th Edition
API TR 6AF1	Technical Report on Temperature Derating on API Flanges under Combination of Loading	2nd Edition
API TR 6AF2	Technical Report on Capabilities of API Flanges Under Combinations of Loading	Phase II - 5th Edition
API SPEC 14A	Subsurface Safety Valve and Annular Safety Valve Equipment	13th Edition
API SPEC 17D	Specification for Subsea Wellhead and Tree Equipment	3rd Edition
API STD 6AV1	Sandy Service Test of Safety and Shutdown Valves	4th Edition

A.8.5 Downhole Equipment Deployment

Identification	Name	Version to Use
API 4F	Specification for Drilling and Well Servicing Structures	
API 4G	RP for Maintenance and Use of Drilling and Well Servicing Structures	
API 5B	Specification for Thread Gauging and Thread Inspection of Casing, Tubing and Line Pipe Threads	
API 5C2	Bulletin on Performance Properties of Casing, Tubing and Drill Pipe	
API 7L	Procedures for Inspection, Maintenance, Repair and Remanufacture of Drilling Equipment	
API 8A	Specification for Drilling and Production Hoisting Equipment	
API 8B	RP for Procedures for Inspection, Maintenance, Repair and Remanufacture of Hoisting Equipment	
API 8C	Specification for Drilling and Production Hoisting Equipment (PSL 1 and PSL 2)	
API 9A	Specification for Wire Rope	
API 9B	RP on Application, Care and Use of Wire Rope for Oil Field Service	
API 54	RP for Occupational Safety for Oil and Gas Well Drilling and Servicing Operations	

A.8.6 Fire Protection

Identification	Name	Version to Use
NFPA 110	Standard for Emergency and Standby Power Systems	
NFPA 855	Standard for the Installation of Stationary Energy Storage Systems	
NFPA 24	Standard for the Installation of Private Fire Service Mains and Their Appurtenances	
NFPA 51B	Standard for Fire Prevention During Welding, Cutting, and Other Hot Work	
NFPA 80	Standard for Fire Doors and Fire Windows	
NFPA 801	Standard for Fire Protection for Facilities Handling Radioactive Materials	

A.8.7 Electrical

General Facility Electrical Codes and Standards

Identification	Name	Version to Use
NFPA 70	National Electrical Code (NEC)	2020 Edition
NFPA 70E	Electrical Safety Requirements for Employee Workplaces	2018 Edition
NFPA 111	Standard on Stored Electrical Energy Emergency and Standby Power Systems	2019 Edition

Normal Power System Codes and Standards

Identification	Name	Version to Use
UL-508A	Standard for Industrial Control Panels	2018 Edition
NETA-ATS	Acceptance Testing Specifications for Electrical Power Distribution Equipment and Systems	2017 Edition

Lighting System Codes and Standards

N/A

Grounding System Codes and Standards

Identification	Name	Version to Use
IEEE-STD 142	IEEE Recommended Practice for Grounding of Industrial and Commercial Power Systems	2007 Edition
NFPA 77	Recommended Practice on Static Electricity	2019 Edition

Lightning Protection System Codes and Standards

Identification	Name	Version to Use
NFPA 780	Standard for the Installation of Lightning Protection Systems	2023 Edition

Telephone System Codes and Standards

N/A

Instrumentation and Controls and Reactivity Control Systems Codes and Standards

Identification	Name	Version to Use
IEEE-1023	IEEE Recommended Practice for the Application of Human Factors Engineering to Systems, Equipment, and Facilities of Nuclear Power Generating Stations and Other Nuclear Facilities	2020 Edition

B. Appendix B – Safety Basis Strategy

B.1 Purpose and Scope

This appendix establishes the Safety Basis Strategy (SBS) for the Deep Fission Gravity Reactor in the form described by DOE-STD-1237-2021, "Preparation of Documented Safety Analyses for DOE Reactor Facilities, Section 4 (Safety Basis Strategy Approach)," for the circumstance in which the Gravity Reactor is authorized as a privately funded, DOE-authorized reactor facility under the requirements of 10 CFR Part 830, Subpart B. Deep Fission's safety analysis process establishes the approach for licensing the Gravity Reactor. This appendix demonstrates that the same integrated process, without restructuring, also satisfies the structured set of SBS requirements that DOE-STD-1237-2021, Section 4, requires to be prepared and submitted to DOE for approval prior to the development of a Documented Safety Analysis (DSA).

The purpose of this appendix is therefore twofold. First, outlines the SBS for the Gravity Reactor by addressing each of the development-approach topics enumerated in DOE-STD-1237-2021, Section 4.0. Second, it maps each of those topics, and the underlying requirements of Sections 4.1 through 4.11, to Deep Fission's process (and, where the topic concerns codes and standards, to Appendix A, Code of Record, of this NSDA) that satisfies the requirement. The mapping is consolidated in the compliance matrix of Section B.15 (Table B-2). Where the correlation between a DOE-STD-1237-2021 requirement and the corresponding Deep Fission process element is not self-evident, explanatory language is provided in the associated subsection of this appendix.

B.2 Relationship to the DOE Authorization Framework and the NSDA

The Gravity Reactor is being developed for authorization under a DOE pathway in parallel with the NRC licensing pathway. Under the DOE pathway, the reactor is a privately funded, DOE-authorized nuclear facility for which the safety basis is established as a DSA prepared in compliance with 10 CFR Part 830, Subpart B, and the authorization is obtained consistent with DOE-STD-1271-2025, "Authorization Pathway for Nuclear Facilities." The overarching nuclear safety design framework, the governing requirements, and the relationship among the safety basis deliverables (the Nuclear Safety Design Agreement (NSDA), the Preliminary DSA (PDSA)/Preliminary Safety Analysis Report (PSAR), and the DSA/Final Safety Analysis Report (FSAR)) are established in this NSDA.

Because Deep Fission constructed its safety analysis process on the deterministic, light-water-reactor (LWR) accident analysis methodology of NUREG-0800, and because that methodology shares its analytical foundation with the DOE-STD-3009-2014 hazard and accident analysis approach endorsed by DOE-STD-1237-2021, the Gravity Reactor safety analysis process produces, in a single analytical effort, the substantive content required by each SBS topic. This appendix records that correspondence and identifies the limited instances in which a DOE-specific expectation is satisfied by reference to a DOE technical standard rather than by an NRC-anchored element of the process.

B.3 Applicability of the DOE-STD-1237-2021 Section 4 Approach

DOE-STD-1237-2021, Section 4.0, provides that the structured SBS approach is used when the pre-approved, reactor-type-based approach of Section 3 is not appropriate for a particular reactor design. The Gravity Reactor is a borehole-emplaced pressurized water reactor (PWR) that relies on INP design features (geologic isolation and a hydrostatic water column nominally one mile tall) to fulfill its fundamental safety functions. This configuration does not correspond directly to any of the pre-approved reactor types of Section 3 (subcritical nuclear assemblies, critical assemblies, other Category B reactors, or Category A reactors), and the pre-approved safety basis strategies associated with those types do not, without substantial modification, fit the Gravity Reactor design. The Section 4 SBS approach is therefore used for the Gravity Reactor.

Consistent with DOE-STD-1237-2021, Section 4.0, the most relevant reactor type of Section 3 is nonetheless evaluated for applicable requirements and guidance in the course of completing the Section 4 requirements. The hazard categorization of the facility is established consistent with NE-STD-1027-2025, Hazard Categorization of DOE Nuclear Facilities and the reactor-type-specific design and analysis expectations of Section 3 are drawn upon where they are relevant to the Gravity Reactor configuration.

The dose acceptance basis of the DOE pathway is also recognized at the outset. DOE-STD-1237-2021, Section 5.2, establishes that the mitigated off-site dose consequence for credible design basis accidents shall not exceed the 25 rem Evaluation Guideline (EG). The Gravity Reactor safety analysis demonstrates, through the bounding Maximum Hypothetical Accident (MHA) analysis, an off-site dose well below the more restrictive 1 rem (0.01 Sv) total effective dose equivalent (TEDE), and therefore well below the 25 rem DOE EG, without credit for any engineered safety-related structure, system, or component (SSC) beyond the fuel itself. The safety basis consequently satisfies the DOE EG with very substantial margin.

B.4 Safety Basis Strategy Topics and Correlation to the Deep Fission Safety Analysis Process

DOE-STD-1237-2021, Section 4.0, requires the SBS to describe the development approach for each of nine topics, as applicable. Table B-1 summarizes each SBS topic and provides a concise statement of correlation to Section 3.2, Safety Analysis Process, of this NSDA. The subsequent subsections (Sections B.5 through B.14) address each topic in turn, and the detailed, requirement-by-requirement compliance matrix is provided in Section B.15 (Table B-2).

Table A-1: Safety Basis Strategy Topic Correlation to the Deep Fission Safety Analysis Process

DOE-STD-1237-2021 SBS Topic (Section)	Correlation Summary
Identification and Use of Industry Codes and Standards (4.1)	The Code of Record identifies the applicable industry codes and standards and the sections used; Deep Fission's safety analysis process invokes the analysis-related industry standards.
Identification and Use of DOE Technical Standards (4.2)	The Code of Record identifies the applicable DOE technical standards (e.g., DOE-STD-3009; NE-STD-1020) and the sections used.
Summary of Design Criteria and Design Requirements (4.3)	Step 1 establishes performance-based PDC from 10 CFR Part 50 GDC, which are analogous to the NE O 420.1 nuclear safety design criteria.
Summary of Process for Hazards Identification and Evaluation (4.4)	Steps 2 and 3 screen the PWR initiating-event families and perform a new-hazard review using HAZOP, What-If, and FMEA.
Summary of Approach to Identify and Analyze Design Basis Accidents (4.5)	Steps 4 through 6 categorize events, select bounding accidents, and perform deterministic and MHA analyses against the dose acceptance criterion.
Summary of Approach to Classification of Hazard Controls (4.6)	Step 7 classifies SSCs (e.g., safety-related, important-to-safety) using a hierarchy of controls, with controls protected by Technical Specifications (Step 9).
Summary of Approach to Use Probabilistic Risk Assessment Insights (4.7)	A deterministic methodology supplemented with risk insights is used; a full-scope PRA is not anticipated, with the optional risk-informed tools identified.
Summary of Approach to Defense in Depth (4.8)	A five-layer defense-in-depth framework is established and is formally evaluated in Step 10.
Format and Content of the DSA (4.9)	The PSAR/FSAR format and content are established consistent with the RG 1.70/RG 1.206 organization used as the DSA safe harbor under 10 CFR Part 830.

B.5 Use of Industry Codes and Standards

DOE-STD-1237-2021, Section 4.1.1, requires the SBS to identify the applicable industry codes and standards and the sections of those standards that will be used, and requires that DOE reactors make use of industry codes and standards to the maximum extent possible when they are available and applicable. For the Gravity Reactor, this requirement is satisfied principally through the Code of Record (COR), established in Appendix A of this NSDA and progressively elaborated during the design development. The COR is the list of codes, standards, and regulatory requirements that Deep Fission has determined to be applicable to the design; it establishes the governing technical framework, provides traceability, documents any equivalencies or exemptions with their supporting technical evaluations, and is placed under configuration control beginning at preliminary design and submitted to DOE for review and approval with each safety basis deliverable. The COR is therefore the controlled instrument through which the Section 4.1.1 identification requirement is met and maintained current as the design matures.

B.6 Use of DOE Technical Standards

DOE-STD-1237-2021, Section 4.2.1, requires the SBS to identify the applicable DOE technical standards and the sections of those standards that will be used, recognizing that certain DOE-specific safety analysis topics (e.g., worker and co-located worker safety, chemical safety, specific administrative controls, and safety management programs) are not fully addressed in industry codes and standards. As with the industry codes and standards, this requirement is satisfied through the Code of Record, which identifies the applicable DOE technical standards and incorporates them into the design and safety analysis basis.

B.7 Summary of Design Criteria and Design Requirements

DOE-STD-1237-2021, Section 4.3, requires the SBS to provide a summary of the design criteria and design requirements that will be applied, recognizing that 10 CFR Part 830 requires the nuclear design criteria of NE O 420.1, "Facility Safety," to be used for new nuclear facilities. For the Gravity Reactor, this requirement is satisfied by Step 1 of the Deep Fission safety analysis process.

Step 1 establishes the PDC for the Gravity Reactor informed by the crosswalk methodology of RG 1.232. These criteria are the functional analog, for the Gravity Reactor, of the nuclear design criteria of NE O 420.1: each addresses the same fundamental safety functions (reactivity control, heat removal, fission product retention/confinement, and shielding) for which NE O 420.1 and DOE G 420.1-1A are directed, and each is established as a controlled design requirement traceable to the credited barriers and safety features. The PDC therefore satisfy, in substance, the design-criteria identification requirement of Section 4.3 and the reactor-specific design criteria expectation of NE O 420.1. Consistent with the Gravity Reactor design philosophy, the PDC developed through Step 1 are expected to be fully performance-based and few in number; they are expressed in measurable, verifiable terms amenable to design verification by analysis, test, inspection, or a combination of these, rather than as prescriptive design specifications. The development, documentation, and configuration control of the PDC are part of Step 1 of Deep Fission's safety analysis process.

DOE-STD-1237-2021, Section 4.3, further directs that the reactor design address three specific topics to the extent relevant.

B.7.1 Acceptable Fuel Design Limits

DOE-STD-1237-2021, Section 4.3.1, requires the DSA to identify acceptable fuel design limits that mark the point at which fuel or cladding damage is expected to occur, providing the criteria against which the transient response of the reactor is compared to determine whether fuel or cladding damage has occurred or been averted. For the Gravity Reactor, this requirement is satisfied through the specified acceptable fuel design limits (SAFDLs) framework in Deep Fission's safety analysis process. The fuel design limits are established as PDC-anchored acceptance criteria in Step 1 and are applied as the fuel-integrity acceptance criteria in the deterministic accident analyses of Step 6. Because the Gravity Reactor uses conventional commercial low-enriched uranium PWR fuel, the extensively qualified SAFDL framework of the operating PWR fleet is directly applicable. The fuel (the fuel matrix and cladding) is, moreover, the engineered SSC anticipated to be classified as safety-related in Step 7, so that its design limits are protected as credited acceptance criteria in the safety case.

B.7.2 Automatic Reactor Shutdown System

DOE-STD-1237-2021, Section 4.3.2, requires that an automatic reactor shutdown system be employed to prevent or minimize fuel and cladding damage in response to evaluated hazardous event scenarios, assuming a single credible failure of the shutdown system mechanism (e.g., the most reactive absorber element remaining stuck out of the core). For the Gravity Reactor, the reactivity-control PDC established in Step 1 credits the Aqueous Reactivity Control and Shutdown (ARCS) System for rapid insertion of reactivity control, supplemented by the strong negative moderator and Doppler temperature coefficients inherent to the LEU oxide-fueled PWR core and by the soluble neutron absorber capacity of the borehole water volume. The single-failure assumption required by Section 4.3.2 is incorporated in the deterministic accident analyses of Step 6, whose inputs and assumptions are selected to be conservative consistent with NUREG-0800, Sections 15.0.1 through 15.0.3 (which embed the single-failure criterion in the limiting transient and accident analyses). The automatic shutdown function and its single-failure-tolerant performance are therefore established as a credited safety function and protected through the corresponding PDC and Technical Specifications.

B.7.3 Residual Heat Removal System

DOE-STD-1237-2021, Section 4.3.3, requires that a residual heat removal system be employed, as needed, to ensure continued cooling of the reactor fuel after shutdown, and permits a technical evaluation to demonstrate, for some lower-power reactors, that such a system is not needed to preclude post-shutdown fuel or cladding damage. For the Gravity Reactor, the heat-removal PDC established in Step 1 credits highly reliable passive decay heat removal provided by natural circulation in the primary coolant loop combined with the immersion of the reactor canister within the hydrostatic water column, which constitutes a very large passive heat sink that bounds the reactor decay heat for the duration of any postulated accident. The credited INP heat-removal feature is qualified through the INP qualification activity of Step 1 and is confirmed by the deterministic analyses of Step 6 to maintain fuel and cladding integrity following shutdown. The demonstration that the passive heat sink precludes post-shutdown fuel damage without reliance on an active residual heat removal system constitutes the technical evaluation contemplated by Section 4.3.3.

B.8 Summary of Process for Hazards Identification and Evaluation

DOE-STD-1237-2021, Section 4.4.1, requires the SBS to provide a summary of the process that will be used for hazards identification and evaluation. Section 4.4.2 identifies the approach of DOE-STD-3009-2014 (further described in DOE-HDBK-1224, Hazard and Accident Analysis Handbook) as acceptable, and expressly permits other approaches that provide an equivalent level of safety if approved by DOE in the SBS. For the Gravity Reactor, hazards identification and evaluation are performed through Step 2 (PWR Transient/Accident Initiating Event Screen) and Step 3 (New Hazard Review) of the Deep Fission safety analysis process.

Step 2 systematically screens the established PWR transient and accident families against the initiating-event categories, and documents, with technical basis, any initiating events precluded by the Gravity Reactor configuration or its INP design features. Step 3 augments that screen with a new-hazard review of the unique hazards introduced by the deep-borehole emplacement and the hydrostatic water column, performed using the structured deterministic methods (Hazard and Operability (HAZOP) study, What-If analysis, and/or Failure Modes and Effects Analysis (FMEA)). These are the same structured hazard-evaluation techniques that underlie the DOE-STD-3009-2014 and DOE-HDBK-1224 methodology; Deep Fission's hazards identification and evaluation process is therefore methodologically equivalent to the DOE-STD-3009-2014 approach and constitutes an approach providing an equivalent level of safety within the meaning of Section 4.4.2, to be approved by DOE through this SBS.

B.9 Summary of Approach to Identify and Analyze Design Basis Accidents

DOE-STD-1237-2021, Section 4.5.1, requires the SBS to provide a summary of the approach that will be used to identify and analyze design basis accidents, and Section 4.5.2 identifies the DOE-STD-3009-2014 approach as acceptable while permitting other approaches of equivalent safety. For the Gravity Reactor, design basis accidents are identified and analyzed through Steps 4 through 6 of Deep Fission's safety analysis process.

Step 4 (Initiating Event Categorization) categorizes each initiating event as an anticipated operational occurrence or a postulated accident using the qualitative likelihood classification. Step 5 (Design Basis Event Categorization) organizes the categorized events into families and identifies, within each family, the bounding postulated accident that drives the safety case. Step 6 (Deterministic Analysis) performs the deterministic safety analyses on each bounding postulated accident and on the facility-wide bounding case using conservative inputs and assumptions consistent with NUREG-0800, Sections 15.0.1 through 15.0.3, the alternative source term methodology of RG 1.183, and the atmospheric dispersion methodology of RG 1.145. The selection and analysis of the facility-wide Maximum Hypothetical Accident (MHA), which is a highly conservative, non-mechanistic bounding accident, is the functional analog of the bounding design basis accident analysis of the DOE-STD-3009-2014 methodology, and the deterministic approach of Steps 4 through 6 is methodologically equivalent to, and provides an equivalent level of safety to, the DOE-STD-3009-2014 design basis accident approach within the meaning of Section 4.5.2. The off-site dose consequences are evaluated against dose acceptance criterion of 1 rem (0.01 Sv) TEDE, which is bounding relative to the 25 rem DOE EG of DOE-STD-1237-2021, Section 5.2.

B.10 Summary of Approach to Classification of Hazard Controls

DOE-STD-1237-2021, Section 4.6.1, requires the SBS to provide a summary of the approach that will be used to classify hazard controls, with Section 4.6.2 identifying the DOE-STD-3009-2014 approach as acceptable while permitting other approaches of equivalent safety. For the Gravity Reactor, hazard control classification is performed in Step 7 (Safety-Related SSC Identification), with the resulting controls protected by the Technical Specifications derived in Step 9.

Deep Fission's safety analysis process establishes the hierarchy of controls applied in the safety analysis (minimization of hazardous material; SSCs preferred over administrative controls; passive SSCs preferred over active; prevention preferred over mitigation; controls closest to the hazard preferred; and controls effective for multiple hazards preferred). This hierarchy is the same control-selection hierarchy embedded in the DOE-STD-3009-2014 and DOE-STD-1189-2016 methodology and in the graded approach. Step 7 then classifies each SSC required by the deterministic accident analyses to keep dose consequences below the acceptance criterion as safety-related and classifies SSCs that perform a fundamental safety function but are not required to meet the dose criterion as important to safety. These two tiers are the functional analog of the safety-class (public protection) and safety-significant (worker protection) control classifications of the DOE-STD-3009-2014 methodology; any specific administrative controls identified are developed consistent with DOE-STD-1186-2016. Deep Fission's control classification approach is therefore methodologically equivalent to, and provides an equivalent level of safety to, the DOE-STD-3009-2014 approach within the meaning of Section 4.6.2.

B.11 Summary of Approach to Use Probabilistic Risk Assessment Insights

DOE-STD-1237-2021, Section 4.7.1, requires the SBS to provide a summary of the approach that will be used to identify and apply probabilistic risk assessment (PRA) insights, if used. Section 4.7.2 identifies DOE-STD-1628-2013 as an acceptable approach for developing PRAs, and Section 4.7.3 permits NEI 18-04 to be used as guidance. Consistent with the graded approach, the Gravity Reactor safety case is established on a deterministic methodology supplemented with risk insights, and a quantitative full-scope PRA is not anticipated to be required, because the INP design features prevent core damage and the bounding MHA appropriately bounds the spectrum of credible design basis accidents. Where additional structured risk insight is useful for prioritization or screening, but a full PRA is not warranted, the Alternative Evaluation for Risk Insights (AERI) methodology of DG-1414 may be applied within Step 3 as a supplementary tool. If, during detailed design, a PRA is found to be useful (for example, to support risk-informed categorization analogous to 10 CFR 50.69), it will be developed consistent with the technical-adequacy guidance of RG 1.200 and the consensus PRA standard ASME/ANS RA-S-1.4; where a DOE PRA is developed, it will conform to DOE-STD-1628-2013, with NEI 18-04 used as guidance, consistent with Sections 4.7.2 and 4.7.3. This graded, deterministic-with-risk-insights approach is the approach to PRA insights established for the Gravity Reactor SBS.

B.12 Summary of Approach to Defense in Depth

DOE-STD-1237-2021, Section 4.8.1, requires the SBS to provide a summary of the approach that will be used to provide defense in depth and to meet the defense-in-depth requirements of NE O 420.1, with Section 4.8.2 identifying the approach of DOE G 420.1-1A as acceptable. For the Gravity Reactor, the defense-in-depth approach is formally evaluated in Step 10 (Safety Analysis Completion Check).

Deep Fission establishes a five-layer defense-in-depth framework (prevention of abnormal operation and failures; control of abnormal operation and detection of failures; control of accidents within the design basis; control of severe facility conditions; and mitigation of radiological consequences beyond the design basis) that is retained from the antecedent Part 50 process and that preserves the DOE-aligned defense-in-depth construct. The framework satisfies the minimum two or more independent layers definition of defense in depth with substantial margin. Step 10 then performs an explicit defense-in-depth evaluation against those seven considerations and the five-layer framework. Deep Fission's defense-in-depth approach provides an equivalent level of safety to, and meets the intent of, the NE O 420.1 defense-in-depth requirements. Supporting historical and methodological context is provided by NUREG/KM-0009, referenced in this NSDA.

B.13 Format and Content of the DSA

DOE-STD-1237-2021, Section 4.9.1, requires the SBS to provide the DSA format and content that will be used and how it satisfies the DSA content requirements of 10 CFR 830.204(b). Deep Fission derived the chapter structure for this DSA while aligning the content with requirements from DOE-STD-1271-2025 and DOE-STD-3009-2014. The DSA has 14 chapters:

1. Introduction and General Description
2. Site Characteristics
3. Design of Systems, Structures, and Components
4. Reactor
5. Reactor Coolant and Cooling Systems
6. Engineered Safety Features
7. Instrumentation and Control Systems
8. Electrical Power Systems
9. Auxiliary Systems

10. Radiation Protection and Waste Management

11. Conduct of Operations and Operational Programs

12. Accident Analysis

13. Technical Specifications

14. Operator Licensing and Human Factors Engineering

B.14 Successor Versions of Standards and DOE Review and Approval

DOE-STD-1237-2021, Section 4.10, permits approved successor versions of cited DOE technical standards and industry codes and standards to be used in developing the DSA if they are identified and included in the SBS and approved by the DOE Safety Basis Approval Authority as providing an equivalent level of safety. Deep Fission's safety analysis process is constructed to accommodate this provision: the process invokes consensus standards with the qualifier "or successor edition" (for example, NQA-1-2017 or successor edition), and the Code of Record is the instrument through which successor versions and project-applicable successors are identified, evaluated for equivalency, and submitted to DOE for approval.

B.15 Compliance Matrix

Table B-2 provides the requirement-by-requirement compliance matrix mapping each requirement of DOE-STD-1237-2021, Chapter 4 (Sections 4.0 through 4.11), to the Deep Fission's approach. The matrix is the crosswalk used to demonstrate that the Gravity Reactor safety analysis process satisfies the Safety Basis Strategy requirements of DOE-STD-1237-2021, Chapter 4.

Table A-2: DOE-STD-1237-2021, Chapter 4, Compliance Matrix

Requirement	Summary	Conformance
4.0	Prepare a Safety Basis Strategy describing the development approach for each applicable topic; submit to DOE for approval.	Met. SBS documented as this appendix to the NSDA.
4.1.1	Identify applicable industry codes and standards and the sections used; use to the maximum extent practicable.	Met via the Code of Record.
4.1.2	Evaluate the enumerated candidate industry codes and standards for applicability.	Met. Candidate standards evaluated through the COR and process.
4.2.1	Identify applicable DOE technical standards and the sections used.	Met via the Code of Record.
4.2.2	Consider the enumerated DOE technical standards (DOE-STD-3009, 1186, 1189, 1020/NE-STD-1020, 1066, 1628).	Met. DOE standards correlated to the applicable process elements.
4.3	Summarize the design criteria and design requirements, consistent with the SDS and DOE O 420.1C nuclear design criteria.	Met. Performance-based PDC established in the PDSA.

Requirement	Summary	Conformance
4.3.1	Identify acceptable fuel design limits.	Met. SAFDL framework (NUREG-0800 Sec. 4.2/4.3) applied as acceptance criteria.
4.3.2	Employ an automatic reactor shutdown system assuming a single credible failure.	Met. ARCS credited; single-failure assumption per NUREG-0800 Sec. 15.0.
4.3.3	Employ a residual heat removal system as needed (technical evaluation may show none required).	Met. Passive heat sink precludes post-shutdown fuel damage; technical evaluation provided.
4.4.1	Summarize the process for hazards identification and evaluation.	Met. PWR initiating-event screen plus new-hazard review.
4.4.2	Use DOE-STD-3009-2014 (or an approved equivalent) for hazards identification and evaluation.	Met. Equivalent-level-of-safety approach approved through this SBS.
4.5.1	Summarize the approach to identify and analyze design basis accidents.	Met. Categorization, bounding-event selection, deterministic and MHA analysis.
4.5.2	Use DOE-STD-3009-2014 (or an approved equivalent) for DBA identification and analysis.	Met. Equivalent-level-of-safety approach approved through this SBS.
4.6.1	Summarize the approach to classification of hazard controls.	Met. Safety-related / important-to-safety classification with hierarchy of controls.
4.6.2	Use DOE-STD-3009-2014 (or an approved equivalent) for hazard control classification.	Met. Equivalent-level-of-safety approach approved through this SBS.
4.7.1	Summarize the approach to identify and apply PRA insights, if used.	Met. Deterministic methodology supplemented with risk insights; full-scope PRA not anticipated.
4.7.2	Use DOE-STD-1628-2013 (or an approved equivalent) for any PRA developed.	Met. DOE-STD-1628 to govern any DOE PRA developed.
4.7.3	NEI 18-04 may be used as guidance.	Met. NEI 18-04 available as guidance.
4.8.1	Summarize the defense-in-depth approach and meet DOE O 420.1C defense-in-depth requirements.	Met. Five-layer framework evaluated.
4.8.2	Use DOE G 420.1-1A (or an approved equivalent) for defense in depth.	Met. Equivalent-level-of-safety approach meeting the NE O 420.1 intent.
4.9.1	Provide the DSA format and content and how it satisfies 10 CFR 830.204(b).	Met. PSAR/FSAR format aligned with DOE-STD-1271-2025 and DOE-STD-3009-2014.
4.9.2	Use RG 1.70 / DOE-STD-3009-2014 / hybrid (NUREG-1537 to augment) for format and content.	Met. Hybrid RG 1.70/1.206 format augmented for DOE-specific topics.
4.10	Approved successor versions of standards may be used if identified in the SBS.	Met. Successors identified and controlled through the COR and revised SBS.
4.11	DOE Safety Basis Approval Authority reviews and approves the SBS (CNS concurrence / CDNS advice); DOE-STD-1104-2016 applies.	Met. SBS submitted for DOE review and approval via this NSDA.

Conformance with the requirements of DOE-STD-1237-2021, Chapter 4, as recorded in Table B-2, demonstrates that the Gravity Reactor safety analysis process, together with the Code of Record, satisfies the Safety Basis Strategy requirements of the Standard. The deterministic, LWR-centric methodology of Deep Fission's process and the DOE-STD-3009-2014-based methodology endorsed by DOE-STD-1237-2021 share a common analytical foundation; the correlations recorded in this appendix establish that the single, integrated process produces the substantive content required by both the NRC licensing pathway and the DOE authorization pathway without restructuring.