From: Mallecia Sutton
Sent: Wednesday, September 20, 2023 3:39 PM
To: TerraPower-NatriumSFRDocsPEm Resource
Subject: TerraPower: Considerations for Low Frequency External Hazards Presentation 1032023
Attachments: TP-LIC-PRSNT-0015 - LFEH NRC 10.3.2023 Engagement Presentation (002).pdf

Hearing Identifier: TerraPower_NatriumSFRDocs_Public
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Mail Envelope Properties (SA9PR09MB48143AB5D3DCF305BDB306C2FEF9A)

Subject: TerraPower Considerations for Low Frequency External Hazards Presentation 1032023
Sent Date: 9/20/2023 3:38:53 PM
Received Date: 9/20/2023 3:38:58 PM
From: Mallecia Sutton

Created By: Mallecia.Sutton@nrc.gov

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Tracking Status: None

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Files	Size	Date & Time
MESSAGE	3	9/20/2023 3:38:58 PM
TP-LIC-PRSNT-0015 - LFEH NRC 10.3.2023 Engagement Presentation (002).pdf	2040337	

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Priority: Normal
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Considerations for Low Frequency External Hazards under a Risk-Informed Performance-Based Licensing Framework

a TerraPower & GE-Hitachi technology

TP-LIC-PRSNT-0015

SUBJECT TO DOE COOPERATIVE AGREEMENT NO. DE-NE0009054

Table of Contents

Meeting Objective

- Inform staff of ongoing efforts to develop strategies for treatment of LFEHs for final design.

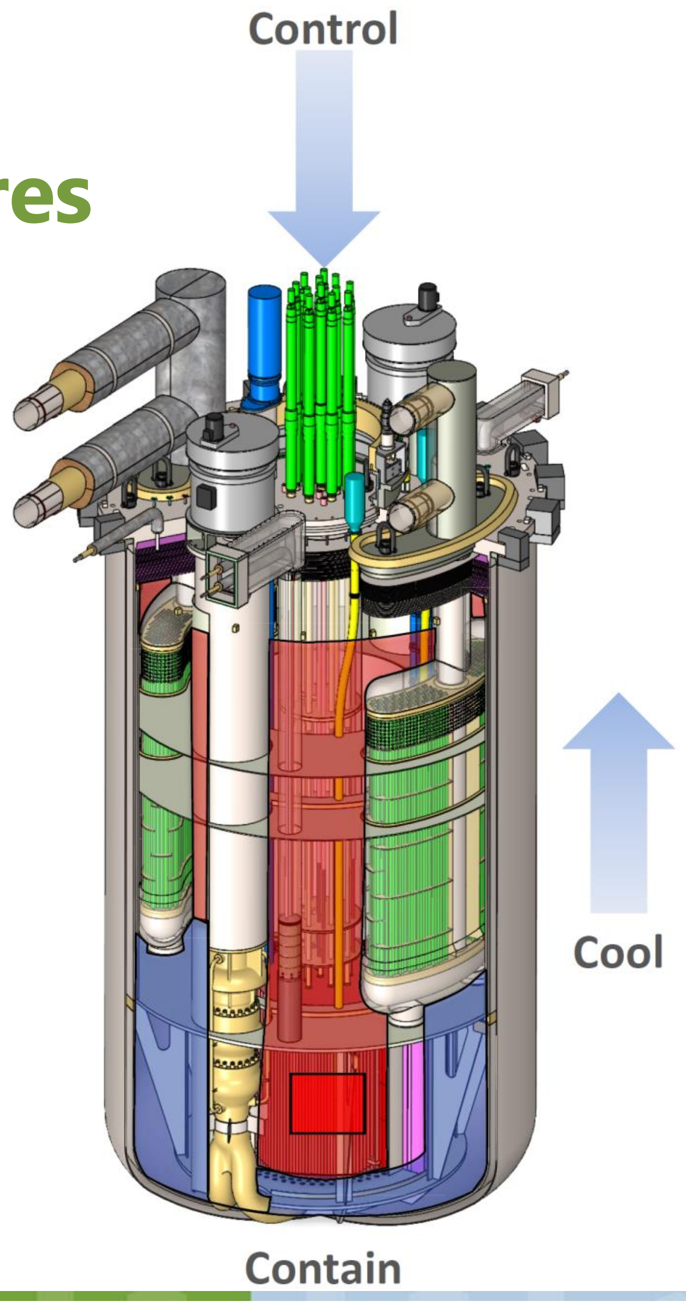
Natrium Reactor Overview

- The Natrium project is demonstrating the ability to design, license, construct, startup and operate a Natrium reactor.

- Pre-application interactions are intended to reduce regulatory uncertainty and facilitate the NRC's understanding of the Natrium design and its safety case.

Natrium Safety Features

- Pool-type Metal Fuel SFR with Molten Salt Energy Island
  - Metallic fuel and sodium have high compatibility
  - No sodium-water reaction in steam generator
  - Large thermal inertia enables simplified response to abnormal events
- Simplified Response to Abnormal Events
  - Reliable reactor shutdown
  - Transition to coolant natural circulation
  - Indefinite passive emergency decay heat removal
  - Low pressure functional containment
  - No reliance on Energy Island for safety functions
- No Safety-Related Operator Actions or AC power
- Technology Based on U.S. SFR Experience
  - EBR-I, EBR-II, FFTF, TREAT
  - SFR inherent safety characteristics demonstrated through testing in EBR-II and FFTF



Control

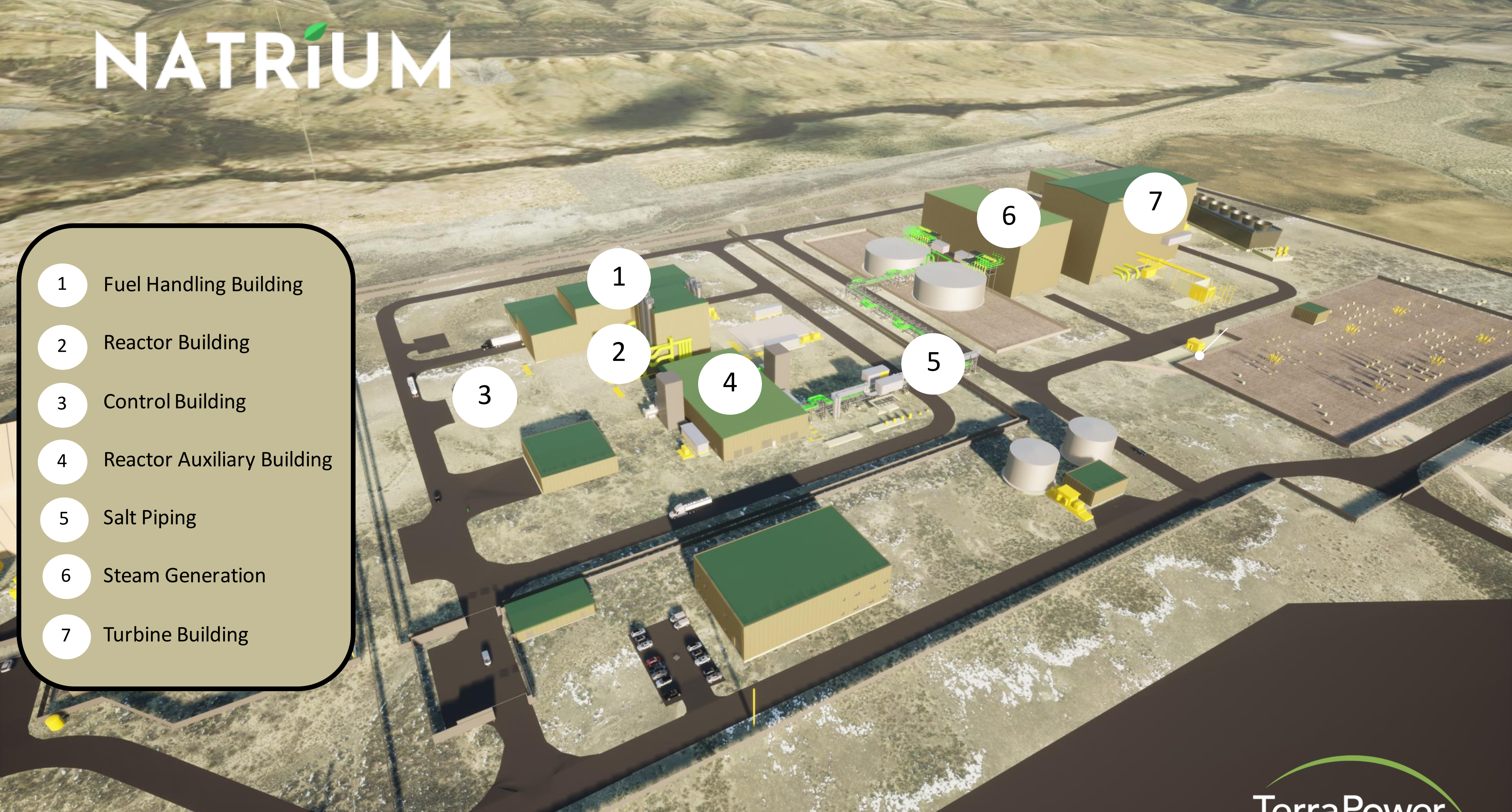
- Motor-driven control rod runback and scram follow
- Gravity-driven control rod scram
- Inherently stable with increased power or temperature

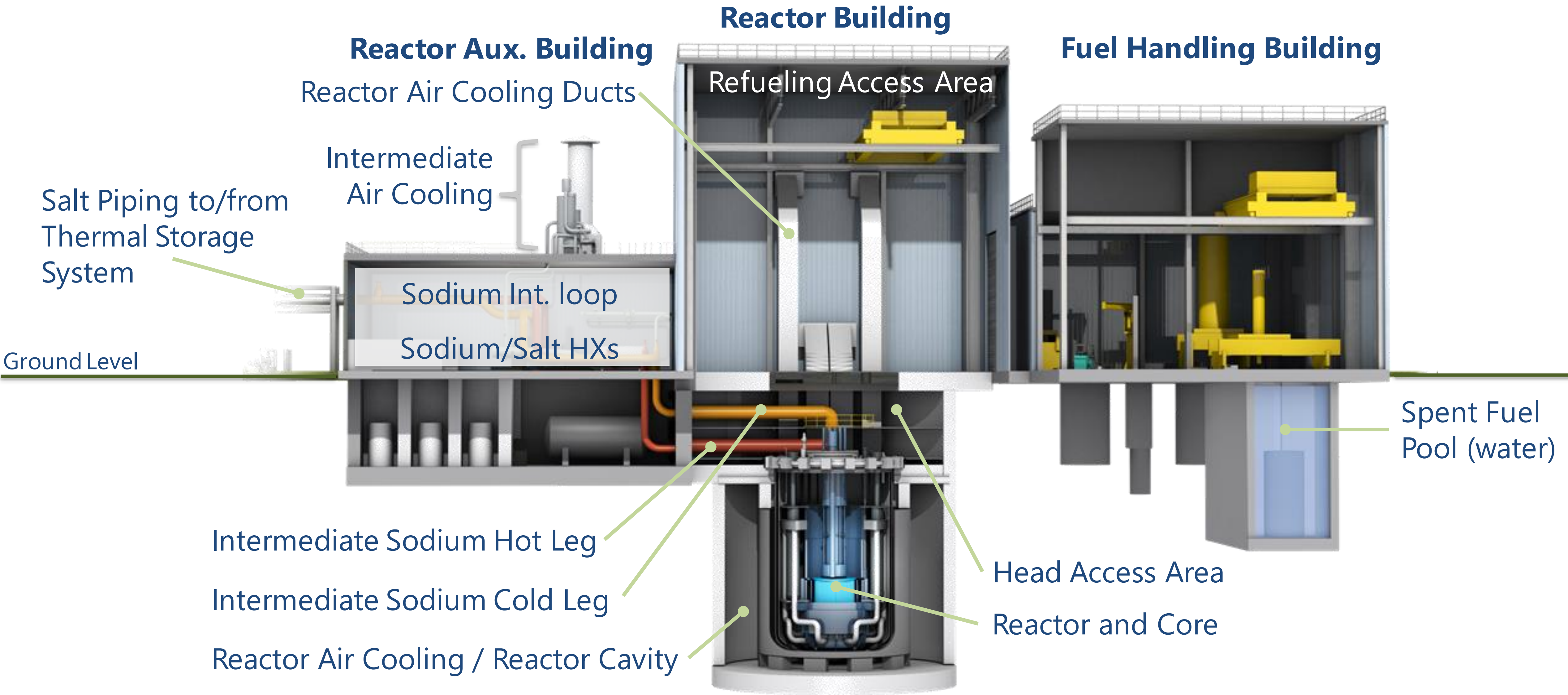
Cool

- In-vessel primary sodium heat transport (limited penetrations)
- Intermediate air cooling natural draft flow
- Reactor air cooling natural draft flow – always on

Contain

- Low primary and secondary pressure
- Sodium affinity for radionuclides
- Multiple radionuclides retention boundaries


NATRIUM
1 Fuel Handling Building
2 Reactor Building
3 Control Building
4 Reactor Auxiliary Building
5 Salt Piping
6 Steam Generation
7 Turbine Building
1
2
3
4
5
6
7
TerraPower
A Nuclear Innovation Company



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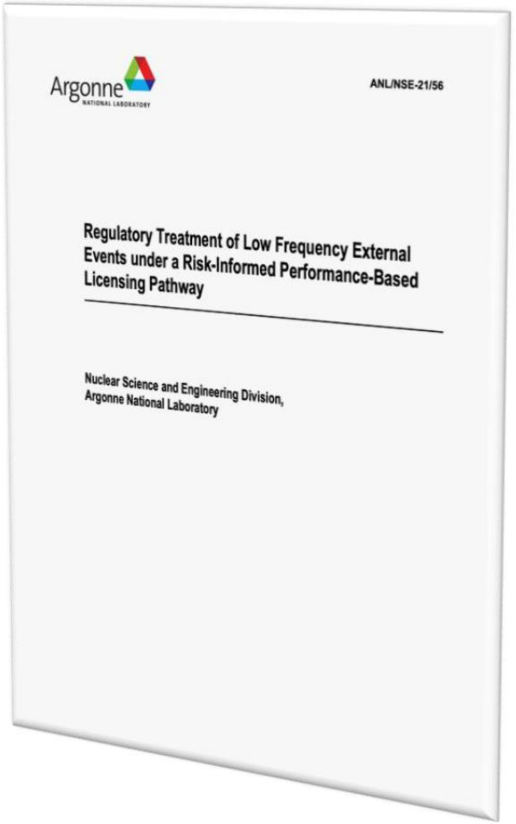
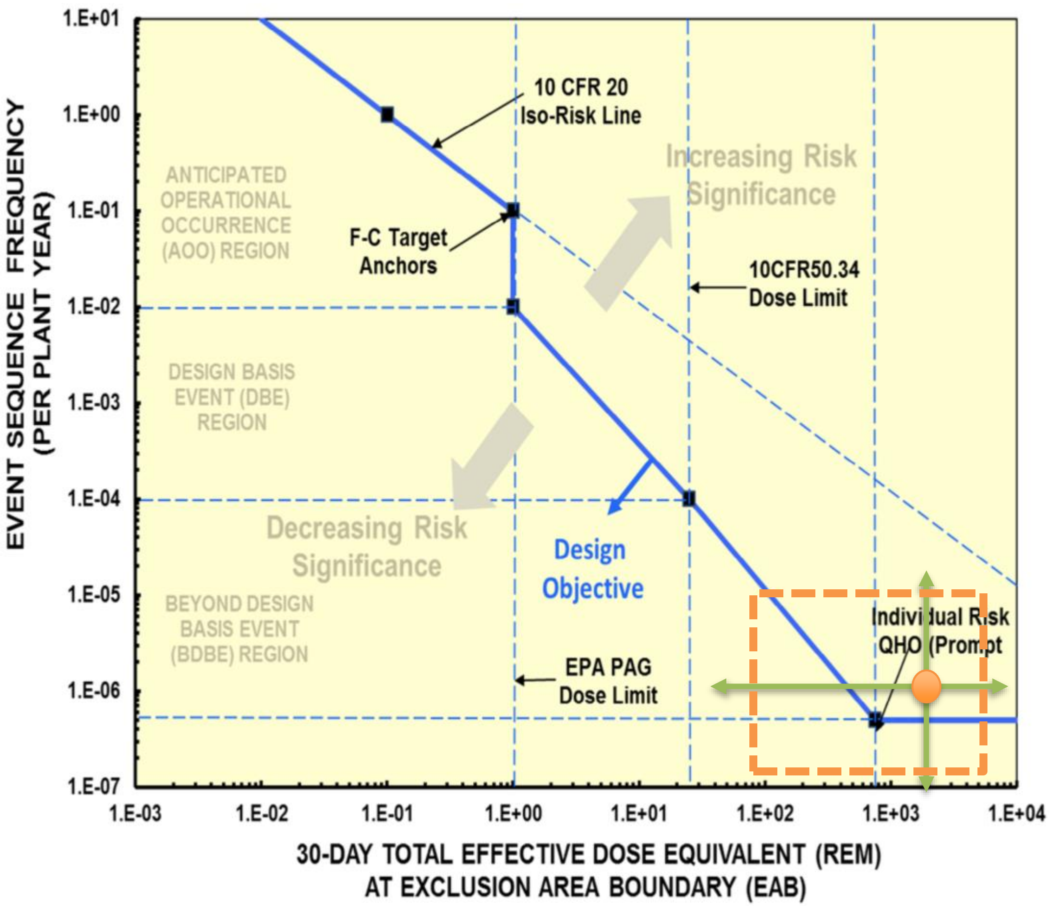
Low Frequency External Hazards – Natrium Challenge

- Summarized in ANL/NSE-21/56: Regulatory Treatment of Low Frequency External Events under a Risk-Informed Performance-Based Licensing Pathway.
- LFEH considerations for Natrium under NEI 18-04:
  - Uncertainty in low frequency hazard range for external events.
  - Coarse assumptions included in early design stage scoping level external hazard PRA may create limiting or unrealistic performance criteria or special treatments.
  - Uncertainty in plant response and dose consequence due to low frequency events.
  - Challenges with calculating NEI 18-04 cumulative risk metrics during initial design iterations without complete external event PRAs.
- LFEH considerations result in challenges to:
  - Treatment and quantification of uncertainty for very rare events.
  - Design and licensing processes.


Argonne
ANL/NSE-21/56
Regulatory Treatment of Low Frequency External Events under a Risk-Informed Performance-Based Licensing Pathway
Nuclear Science and Engineering Division, Argonne National Laboratory

Low Frequency External Hazards – Uncertainty

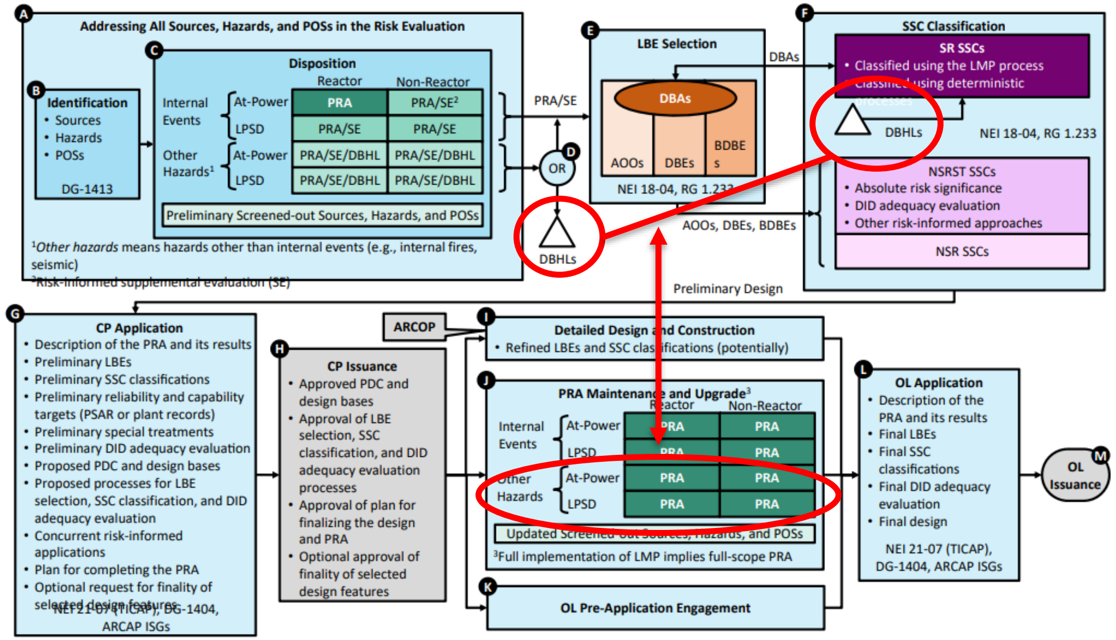
- External hazard characterization for very rare events lacks data:
  - Range of seismic hazards in the BDBE region correspond to very strong motions at orders of magnitude beyond the DBHL using NRC-approved methodologies:
    - Record does not stretch that far.
    - High uncertainty due to extrapolation.
- External events with high uncertainty challenge decision-making:
  - Current understanding of mechanistic source interactions at strong seismic motions lacks experience basis and highlights uncertainty.
- High uncertainty and wide-ranging assumptions challenge meeting the risk metrics.



Ref: NEI 18-04

Low Frequency External Hazards – Design and Licensing

- Natrium licensing basis under 10 CFR Part 50 per NEI 18-04:
  - Selection of LBEs and safety classification of SSCs.
  - Develop performance requirements and application of special treatments.
  - DID adequacy.
- Design and Licensing Challenges:
  - SSC design requirements and special treatments to satisfy DBHL vs DID and NEI 18-04 LBEs:
    - Reconciliation of seismic DBHL with full implementation of NEI 18-04 between CPA and OLA.
    - Treatment of F-C target exceedances for very rare events with high uncertainty.



Ref: USNRC 18 April 2023 Meeting, ADAMS Accession No. ML23101A123

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Low Frequency External Hazards – Natrium Approach

- Evaluating methodologies for treatment of LFEHs under a RIPB framework:
  - Collaborative effort between licensing, engineering, and risk analysis.
  - Engaging national laboratory and industry support.
  - Performing regulation, regulatory guidance, and literature review.
  - Evaluating risk insights from scoping level seismic PRA.
  - Options development, alternatives selection, and integrated decision-making.

Documents Reviewed

- **NEI 18-04** Risk-Informed Performance-Based Technology Inclusive Guidance for Non-Light Water Reactor Licensing Basis Development
- **NEI 21-07** Technology Inclusive Guidance for Non-Light Water Reactors Safety Analysis Report Content for Applicants Using the NEI 18-04 Methodology
- **10 CFR Part 50/52**
- **RG 1.200** An Approach for Determining the Technical Adequacy of Probabilistic Risk Assessment Results for Risk-Informed Activities
- **RG 1.247** Acceptability of Probabilistic Risk Assessment Results for Non-Light-Water Reactor Risk Informed Activities
- **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
- **ASME/ANS RA-S-1.4-2021** Non-Light-Water Reactor PRA Standard
- **NUREG-0800 Chapter 19.0** Severe Accidents
- **DG-1410** Technology-Inclusive, Risk-Informed, and Performance-Based Methodology for Seismic Design of Commercial Nuclear Plants
- USNRC 18 April 2023 Meeting, ADAMS Accession No. ML23101A123: PRA used to Implement LMP for Non-LWR CP Applications Under 10 CFR Part 50
- USNRC 6 July 2023 Meeting, ADAMS Accession No. ML23180A289: Acceptability of a PRA Supporting a Non-LWR Construction Permit Application Based on the LMP Methodology
- **DG-1404** Draft Regulatory Guide: 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
- **DG-1413** Draft Regulatory Guide: Technology-Inclusive Identification of Licensing Events for Commercial Nuclear Plants
- **ANL/NSE-21/56 and ANL/NSE-23/19 (Draft)** Regulatory Treatment of Low Frequency External Events under a Risk-Informed Performance-Based Licensing Pathway

Review of Guidance, Regulations, and Precedent

- Gaps identified during implementation of seismic hazard under NEI 18-04:
  - PRA scope under Part 50:
    - Maturity of risk analyses at CPA and reconciliation of seismic DBHL with full scope external hazards PRA at OLA.
  - LBE selection process and acceptance criteria:
    - Treatment of F-C target exceedances and quantification and treatment of uncertainty for LFEHs.
  - Alternative methods under NEI 18-04:
    - Margin-based approaches to evaluate LFEHs under NEI 18-04.

PRA Scope Under Part 50 at CPA

- Interpretation:
  - LBEs and SSC classification - internal events PRA only.
  - A DBHL-based safety assessment is acceptable for external hazards:
    - Considers a DBHL external hazard level for which SR SSCs will be designed to withstand the effects of the seismic DBHL without loss of capability to perform their RSFs.
      - No LBEs generated from external hazards PRA.
    - Expectation is no new DBAs introduced by external hazards at OLA if the SR SSCs identified for the DBAs at CPA are designed to perform their RSFs.
      - This may require introduction of a seismic DBA at CPA.
  - Plan to complete the external hazards PRA at OLA and reconciliation with seismic DBHL.

- Observation:
  - Preliminary risk insights from scoping level external hazards PRA can be used to support identification of event sequences and phenomena significant to a seismic DBA at CPA in support of the seismic DBHL:
    - No other LBEs will be generated from external hazards PRA at CPA.
  - Reconciliation of seismic DBHL at CPA with full implementation of NEI 18-04 at OLA introduces design and licensing complexity.

PRA Scope Under Part 50 at OLA

- Interpretation:
  - Full scope internal and external hazards PRA is required for full implementation of NEI 18-04.
  - LBEs and SSC classification at CPA are reconciled at OLA.
  - Final design should demonstrate:
    - Meeting cumulative risk metrics.
    - Satisfaction of DBA SR SSC requirements and 10 CFR 50.34 dose limits.
    - DID considerations.
- Observation:
  - SSC design requirements to satisfy external hazard DID considerations and BDBE cumulative risk metrics are not expected to be identified for CPA using seismic DBHL.
    - SSC design requirements to satisfy seismic DBHL are not expected to be sufficient to meet F-C target for the entire BDBE region.
  - Design and procurement progresses at risk when full range of special treatments to satisfy risk metrics, dose limits, DID considerations and F-C target are not known at CPA.

PRA Scope Under Part 50

- Interpretation:
  - ASME/ANS non-LWR PRA Standard permits developing a fit-for-purpose PRA using simplifications and screening criteria:
    - NEI 18-04 screening criteria are more restrictive and governs.
  - NRC 6 July 2023 meeting noted hazard groups, LBEs, and Plant Operating States that require a PRA to meet specific capability categories at CPA and OLA.

- Observations:
  - NEI 18-04 screening criteria and communications from the July 6 meeting are more prescriptive than guidance in the non-LWR PRA Standard.
  - A PRA-based seismic margins assessment supplemental evaluation is not required at CPA.
  - CPA to include seismic design adequacy to support DBAs.

LBE Selection Process and Acceptance Criteria

- Interpretation:
  - The F-C target does not depict acceptance criteria or actual regulatory limits.
  - Exceedance of the F-C target is acceptable if the mean cumulative risk metrics are met:
    - ESFs with 95% confidence frequency exceeding the F-C target will be identified as LBEs.
    - RIPB DID evaluation shall consider these ESFs.
- Observations:
  - Treatment and quantification of uncertainty has high impact on acceptability of exceeding the F-C target and meeting cumulative risk metrics:
    - Quantifying 95% confidence frequency is challenging due to high uncertainty associated with hazard characterization and plant response at LFEH levels.
    - Further uncertainty introduced by different approaches for ESF grouping (model uncertainty per NUREG-1855).
  - Given high uncertainty around evaluation of F-C target exceedance for LFEH events, alternative methods to evaluate sufficient SSC special treatment and plant capability DID adequacy may be more appropriate.

Alternative Methods Under NEI 18-04

- Interpretation:
  - Part 53 - acceptability for using plant-level margins-based approaches considering deterministic DBHLs for external hazards (DG-1414), consistent with regulatory precedent.
  - RG 1.200 - seismic margin method is not an acceptable approach to meeting the attributes and characteristics of a seismic PRA because it does not result in the definition and quantification of seismically induced accident sequences.
  - RG 1.247 - seismic margin methods are outside the scope and would be addressed on a case-by-case basis.

- Observations:
  - A seismic margins assessment may be acceptable under Part 50 and NEI 18-04 if seismically induced accident sequences are defined and quantified.
    - A PRA-based seismic margin assessment may be more appropriate to support SSC design requirement development, consistent with RG 1.208 as basis for seismic DBHL.
  - NEI 18-04 provides no explicit consideration for seismic margin assessment or proxy methods.
    - A risk-informed supplemental evaluation (e.g., PRA-based seismic margin assessment) in conjunction with RG 1.208 DBHL may be an acceptable alternative to full scope seismic PRA at OLA.

Path Forward on Design, Licensing, and Risk Analysis Strategy Development

- Design:
  - Address near term needs for seismic performance criteria to advance design and procurement.
- Licensing:
  - Develop methodology for reconciliation of external hazard DBHL at CPA and complete external hazard PRA at OLA.
  - Potential considerations for treatment of LFEHs:
    - PRA with explicit cumulative risk metric computation (conformance to NEI 18-04).
    - Fit-for-purpose PRA with alternative proxy/risk metrics (deviation from NEI 18-04).
    - PRA-based margins approach that demonstrates implicit satisfaction of cumulative risk metrics (deviation from NEI 18-04).
    - A hybrid or combination of approaches (deviation from NEI 18-04).
- Risk analysis:
  - Develop methodology for seismic ESF grouping and uncertainty quantification.
  - Developing criteria for PRA application consistent with treatment of LFEHs.

Seismic External Hazard Considerations for PSAR

- Present seismic DBHL and introduce a seismic DBA at CPA:
  - Seismic DBA will evaluate the plant response at the DBHL.
    - Seismic DBHL will be established consistent with RG 1.208.
  - SR SSCs will be designed to withstand the effects of the seismic DBHL without loss of capability to perform their RSFs.
- No seismic LBEs, including corresponding DBAs, will be generated from the scoping level seismic PRA at CPA.
  - Margin considered via IDP actions to establish DID adequacy.
  - No separate risk-informed supplemental seismic evaluation for margin.
- Use of seismic PRA will be expanded at OLA stage.
- Outline a treatment of LFEHs and methodology to reconcile the seismic DBHL with a complete external hazard PRA at OLA.

Seismic External Hazard Considerations for PSAR

- Role of a scoping level seismic PRA to support IDP actions to establish DID adequacy:
  - Confirm initial assignments of seismic classifications on the system/major component level.
    - Consistent with January 26, 2023, Natrium NRC Pre-Engagement: PSAR Seismic Analysis and Seismic SSC Classification Approach.
  - Identify top seismic risk contributors, seismic special treatments, and performance criteria to progress and support design and procurement.
  - Support identification of event sequences and phenomena significant to a seismic DBA and the IDP.

Questions?

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Acronym List

AC – Alternating Current
ADAMS – Agencywide Documents Access and Management System
ANL – Argonne National Laboratory
AOO – Anticipated Operational Occurrence
BDBE – Beyond Design Basis Event
CDF – Core Damage Frequency
CFR – Code of Federal Regulations
CP – Construction Permit
CPA – Construction Permit Application
DBA – Design Basis Accident
DBE – Design Basis Event
DBHL – Design Basis Hazard Level
DG – Draft Guidance
DID – Defense-in-Depth
EAB – Exclusion Area Boundary
EBR – Experimental Breeder Reactor
EPA – Environmental Protection Agency
ESF – Event Sequence Family
F-C – Frequency - Consequence
FFTF – Fast Flux Test Facility
HX – Heat Exchanger
IDP – Integrated Decision-Making Process
LBE – Licensing Basis Event
LFEH – Low Frequency External Hazard
LMP – Licensing Modernization Project
NEI – Nuclear Energy Institute
LWR – Light Water Reactor
NRC – Nuclear Regulatory Commission
NSRST – Non-Safety-Related with Special Treatment
OLA – Operating License Application
PAG – Protective Action Guide
PRA – Probabilistic Risk Analysis
PSAR – Preliminary Safety Analysis Report
QHO – Quantitative Health Objective
RG – Regulatory Guide
RIPB – Risk-Informed Performance-Based
RSF – Required Safety Function
SFR – Sodium Fast Reactor
SR – Safety-Related
SSC – Structure, System, and Component
TREAT – Transient Reactor Test