TerraPower

NATRIUM

Severe Accident Mitigation Design Alternatives (SAMDAs)

a TerraPower & GE-Hitachi technology

TP-LIC-PRSNT-0012

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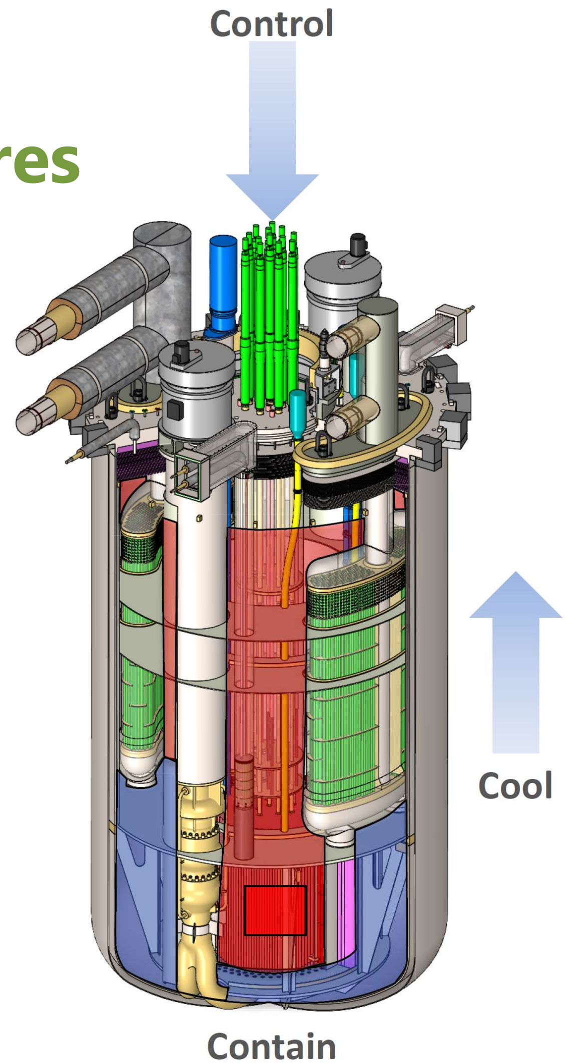
Natrium Reactor Overview

- 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

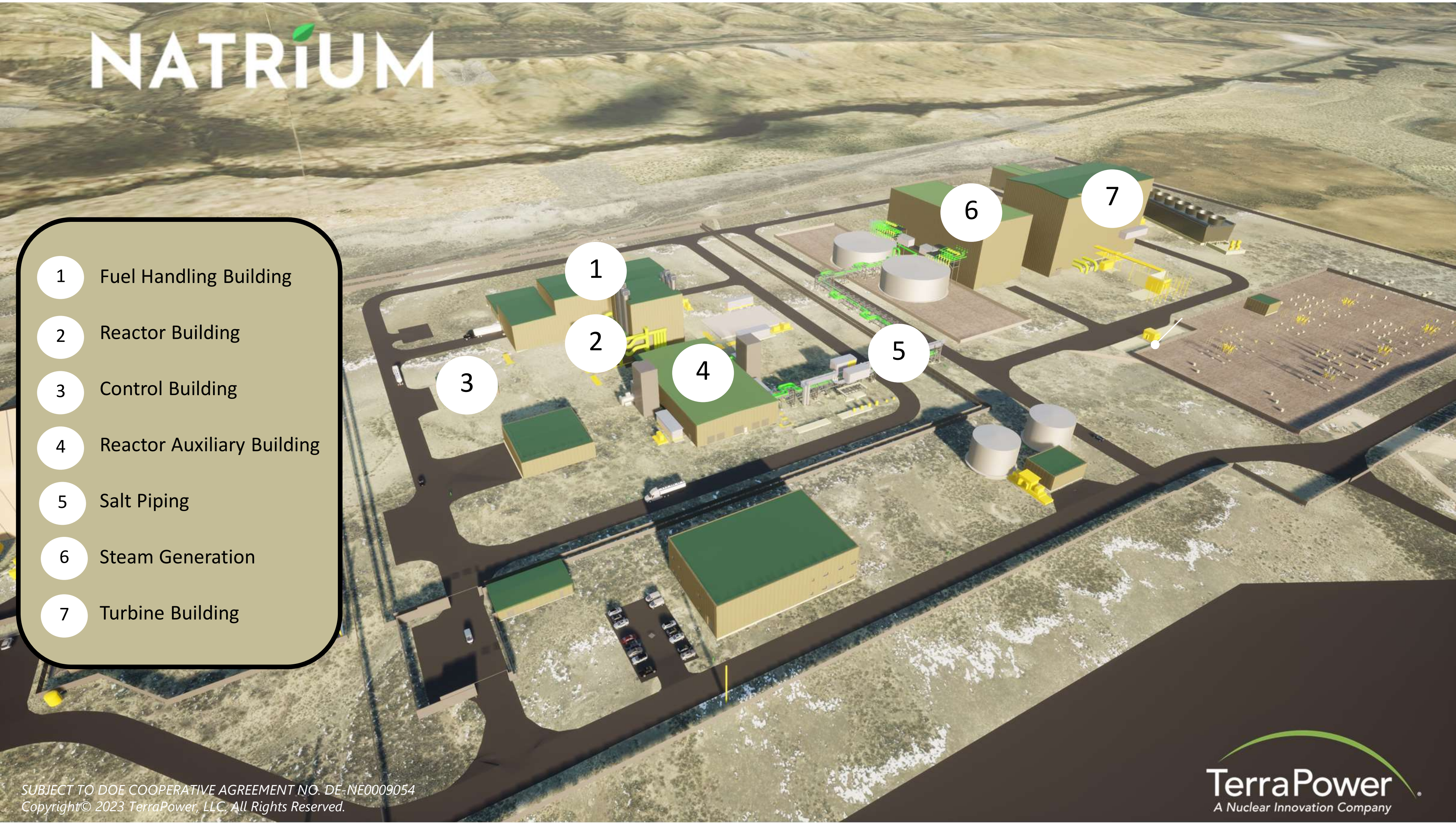
- Motor-driven control rod runback and scram follow
- Gravity-driven control rod scram
- Inherently stable with increased power or temperature

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
SUBJECT TO DOE COOPERATIVE AGREEMENT NO. DE-NE0009054
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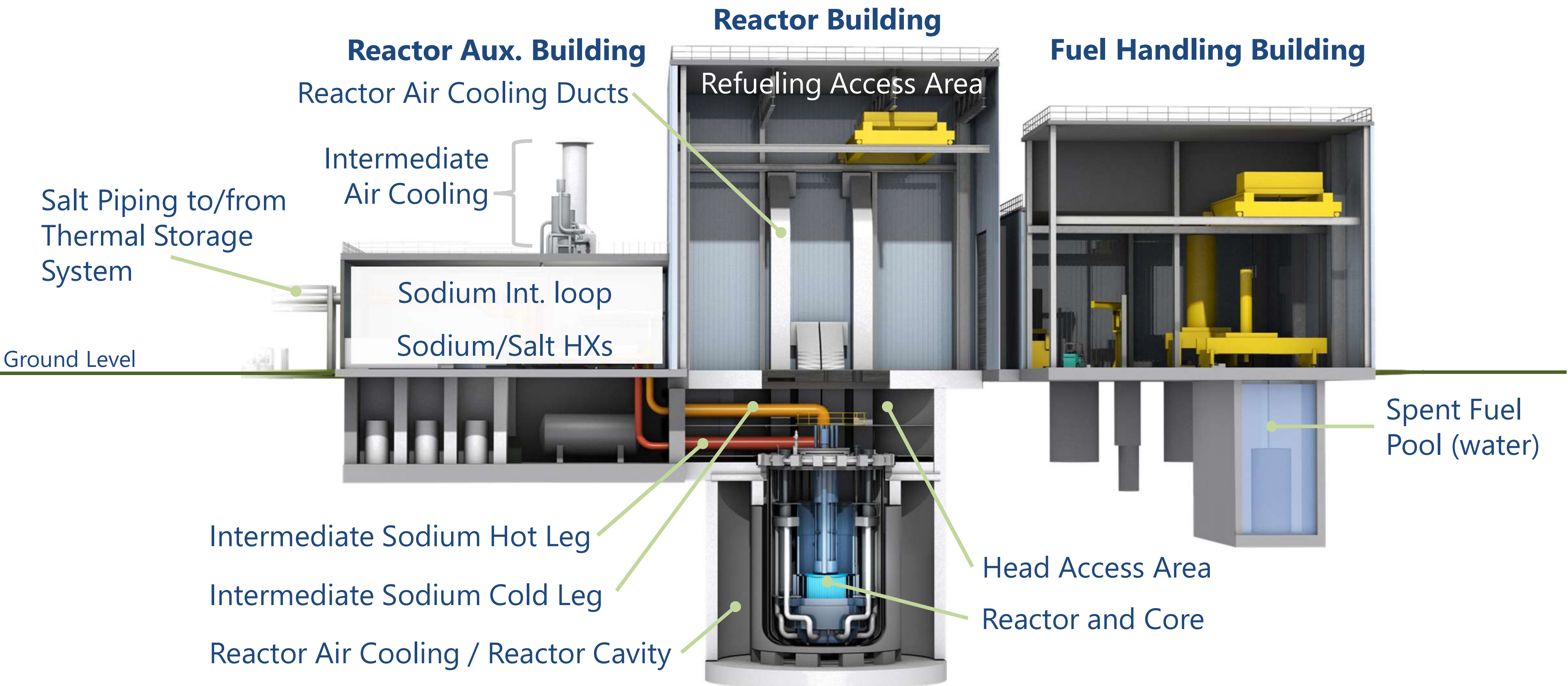


Reactor Building
Reactor Aux. Building
Fuel Handling Building
Reactor Air Cooling Ducts
Refueling Access Area
Intermediate Air Cooling
Salt Piping to/from Thermal Storage System
Sodium Int. loop
Sodium/Salt HXs
Ground Level
Spent Fuel Pool (water)
Intermediate Sodium Hot Leg
Intermediate Sodium Cold Leg
Reactor Air Cooling / Reactor Cavity
Head Access Area
Reactor and Core

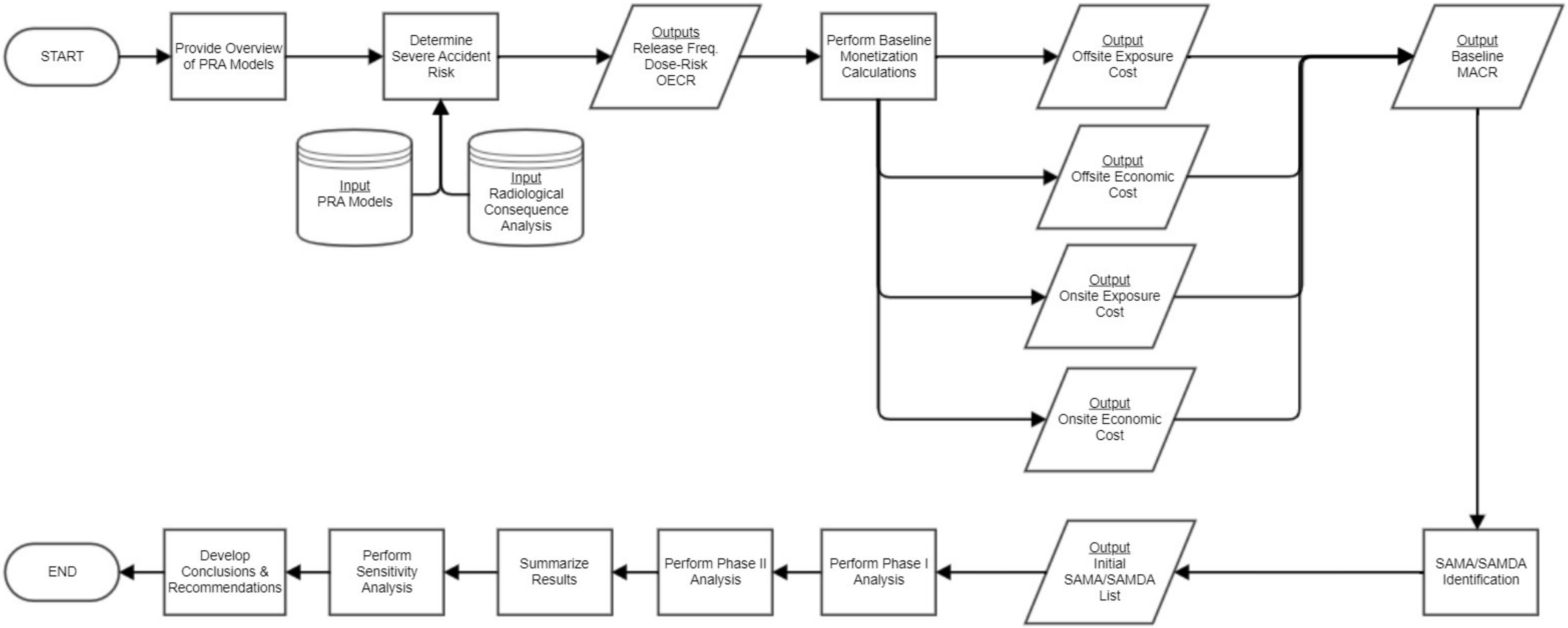
Methodology

- Utilize NEI 05-01, Rev. A for SAMA/SAMDA
  - SAMA: Alternatives supporting subsequent licensing renewal activities.
  - SAMDA: A subset of SAMA focused on potential design changes supporting initial licensing activities.
- No planned deviations of methodology.
- Process will include:
  - Determine Severe Accident
  - Determine Cost of Severe Accident Risk/Maximum Benefit
  - SAMA/SAMDA Identification
  - Preliminary Screening (Phase I SAMA/SAMDA Analysis)
  - Final Screening (Phase II SAMA/SAMDA Analysis)
  - Sensitivity Analysis
  - Conclusions & Recommendations

Justification for Use of NEI 05-01, Rev. A

- RG 4.2 Preparation of Environmental Reports for Nuclear Power Stations, Rev. 3, Footnote 15 (page 122) states the following:
  - *"NEI 05-01, Revision A, "Severe Accident Mitigation Alternatives (SAMA) Analysis, Guidance Document," provides a template for completing SAMA analysis in support of reactor license renewal.* ***If applied as a guidance document for new reactor applications, the applicant should justify its use in the ER****."*
- NEI 05-01, Rev. A provides the latest industry guidance for performing a SAMA/SAMDA evaluation.
  - It has been successfully implemented for operating nuclear power stations and the methodology is flexible enough to apply to advanced reactors.
  - Lessons learned from the operating fleet applications will be incorporated into the SAMA/SAMDA evaluation to ensure that the evaluation is comprehensive.

Process Flowchart



Determine Severe Accident Risk – PRA Models

- An overview of the PRA models used for the SAMA/SAMDA analysis:
  - Modes of operations included in the model.
  - Applicability of external hazards.
  - Definitions of consequence bins/release categories/source term categories as defined in the PRA.
  - Quantification process and results.
  - Key risk insights (e.g., top initiating events, top accident classes/sequences, etc.).
  - Overall PRA quality as compared to the ASME/ANS PRA Standard for Non-Light Water Reactors.

Natrium Specific Considerations

- Industry average multiplier may be used as surrogate for some of the cost estimates as needed.
- Natrium definition of Severe Accident:
  - Any event that has the potential* to exceed 25 rem TEDE 30-day dose at the EAB within 2 hours of the event or at the LPZ for the entire duration of the event (consistent with 10 CFR 50.34 limits).
- Use of SAMA/SAMDA analysis to evaluate implementation of mitigative changes to address events exceeding F-C target.

** Potential is defined as the ability to produce enough radioactive material to achieve a 25 rem release, but the release may be contained by functional containment.*

Design Integration

- The SAMA/SAMDA process creates the avenue for evaluating the alternative mitigative responses to severe accidents.
- The process performs a cost/benefit analysis to see if there is a net positive return for implementing the alternative mitigative response.
- This process will be utilized to evaluate design alternatives to address specific severe accidents.

Design Integration cont.

- Events that exceed the F-C target will have alternative design options evaluated using the SAMA/SAMDA process.
  - If cost beneficial design alternatives exist, then an alternative will be implemented that reduces the dose consequences of the event below the F-C target.
  - If no cost beneficial design alternatives exist, no design alternatives will be implemented, and the event will remain outside the F-C target. Qualitative considerations may be implemented as reasonably achievable (e.g., detailed event discussions in procedures, training, etc.).


Questions?

Acronym List

ANS – American Nuclear Society
ASME – American Society of Mechanical Engineers
CFR – Code of Federal Regulations
DID – Defense-in-Depth
EAB – Exclusion Area Boundary
EBR – Experimental Breeder Reactor
ER – Environmental Report
F-C target – Frequency-Consequence target
FFTF – Fast Flux Test Facility
LBE – Licensing Basis Event
LPZ – Low Population Zone
MACR – Maximum Averted Cost-Risk
NEI – Nuclear Energy Institute
OECR – Offsite Economic Cost-Risk
PRA – Probabilistic Risk Assessment
SAMA – Severe Accident Mitigation Alternatives
SAMDA – Severe Accident Mitigation Design Alternatives
SFR – Sodium Fast Reactor
TEDE – Total Effective Dose Equivalent
TREAT – Transient Reactor Test