TerraPower

NATRIUM

Natrium™ SSC Classification

a TerraPower & GE-Hitachi technology

SUBJECT TO DOE COOPERATIVE AGREEMENT NO. DE-NE0009054

Objectives

- Natrium™ Reactor Overview
- SSC Classification using LMP
- Application of DID

Natrium Reactor Licensing Overview

- Regulatory Engagement Plan submitted 6/8/2021
- 10 CFR 50 licensing process will be followed
  - Construction Permit Application 8/2023
  - Operating License Application 3/2026
- Numerous pre-application interactions are planned to reduce regulatory uncertainty and facilitate the NRC's understanding of Natrium technology and its safety case
- LMP (NEI 18-04), as endorsed by Regulatory Guide 1.233, will support this application

Natrium Reactor Licensing Overview

- Each pre-application interaction will build upon risk insights from prior interactions to demonstrate the Natrium reactor's safety case.

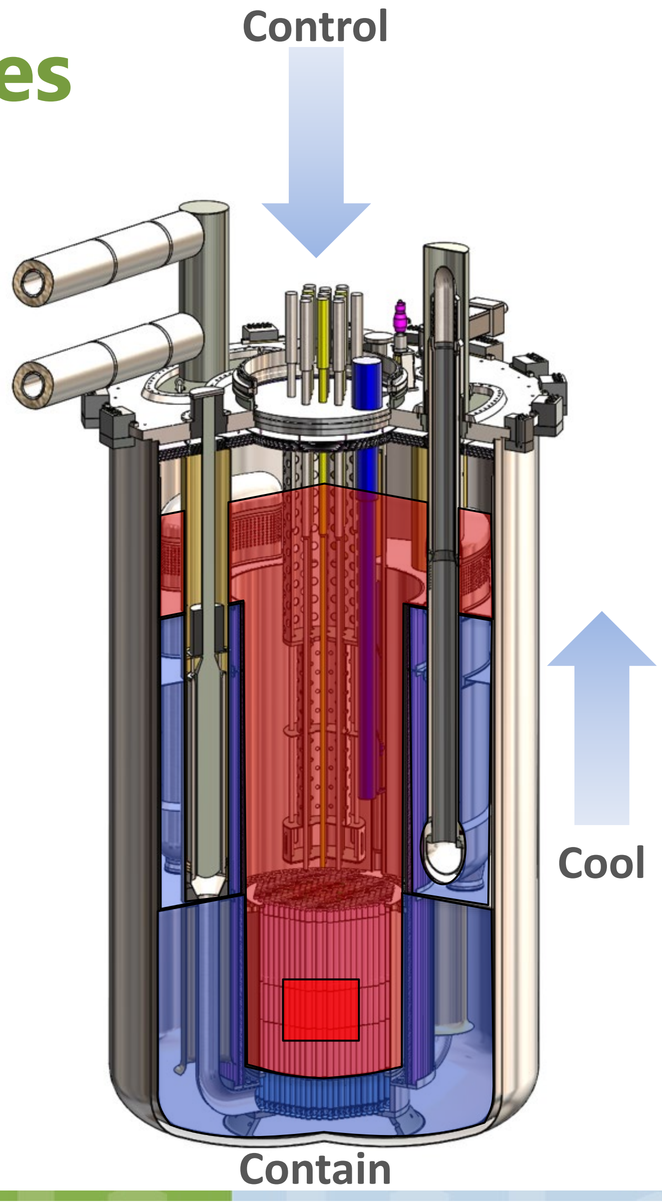
- Future meetings and presentations include:
  – RIPB Principal Design Criteria
  – Energy Island Decoupling Strategy
  – Testing Plan and Methodology

Advanced Reactor Demonstration Program

- Demonstrate the ability to design, license, construct, startup and operate the Natrium reactor within the Congressionally mandated seven-year timeframe
- Include improvements in safety, security, economics, and environmental impacts
- Utilize a simple, robust, reliable, and proven safety profile
- Lower emissions by initiating the deployment of a fleet of Natrium reactors – Demonstrate that the plants can be built economically and that they will be attractive for future owner/operators

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
- 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

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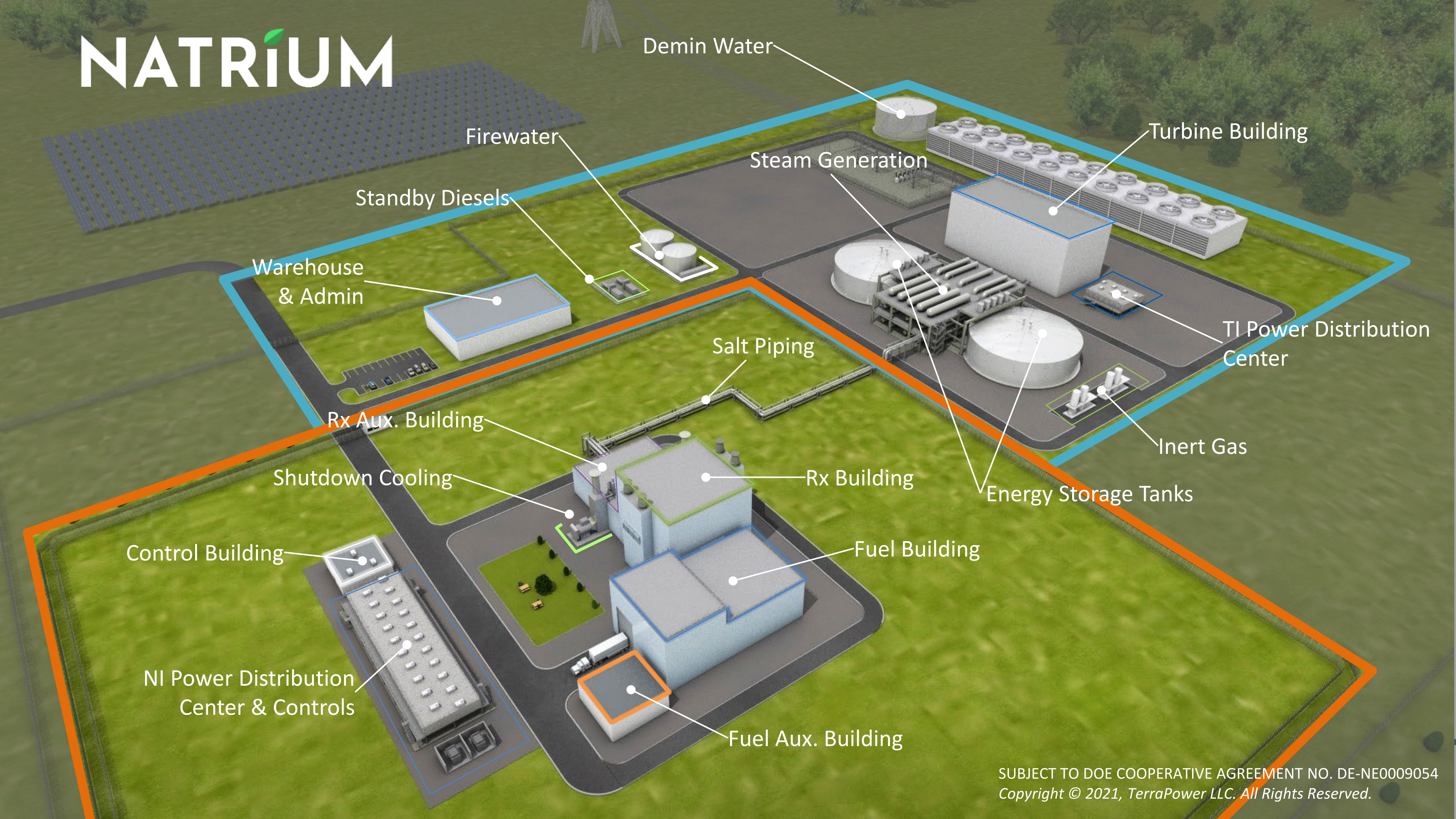
NATRIUM
Demin Water
Firewater
Turbine Building
Steam Generation
Standby Diesels
Warehouse & Admin
TI Power Distribution Center
Salt Piping
Rx Aux. Building
Inert Gas
Shutdown Cooling
Rx Building
Energy Storage Tanks
Fuel Building
Control Building
NI Power Distribution Center & Controls
Fuel Aux. Building
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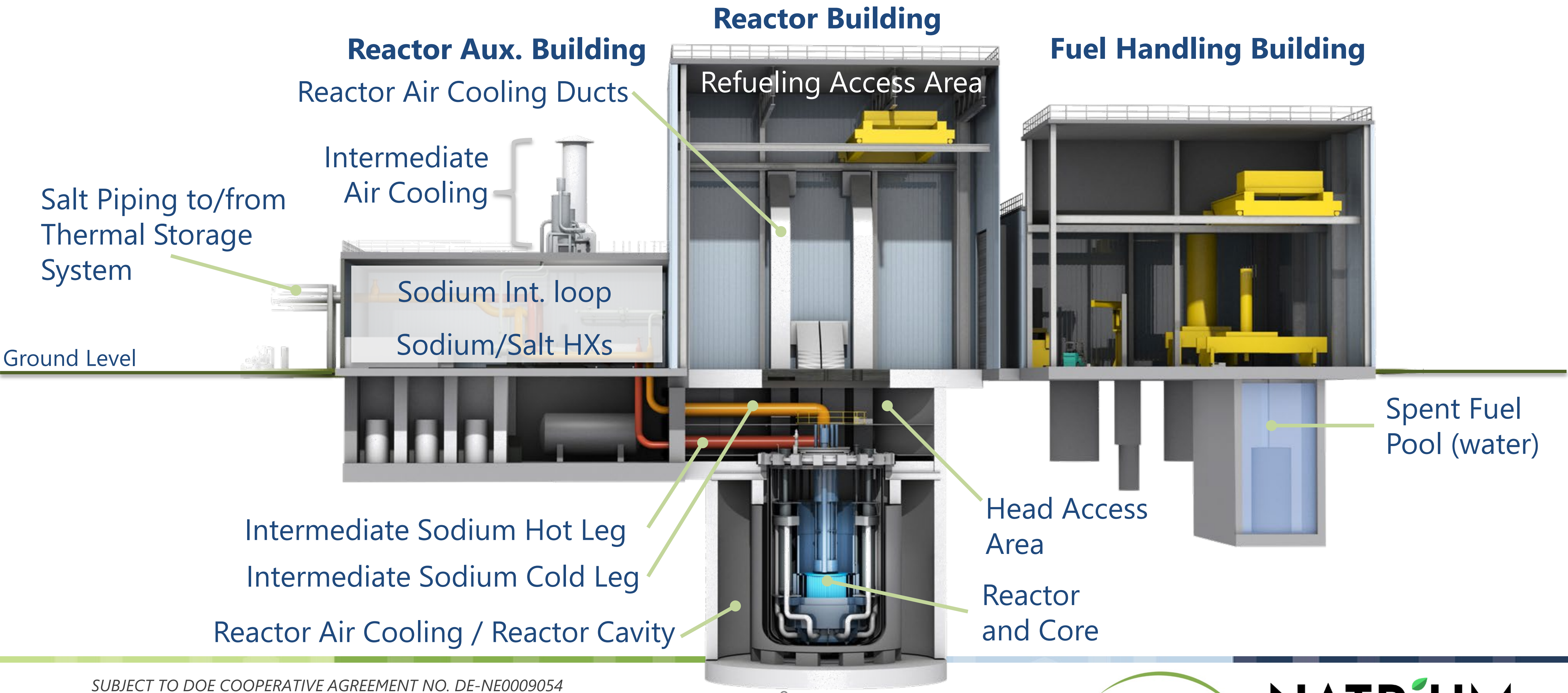
Plant Overview



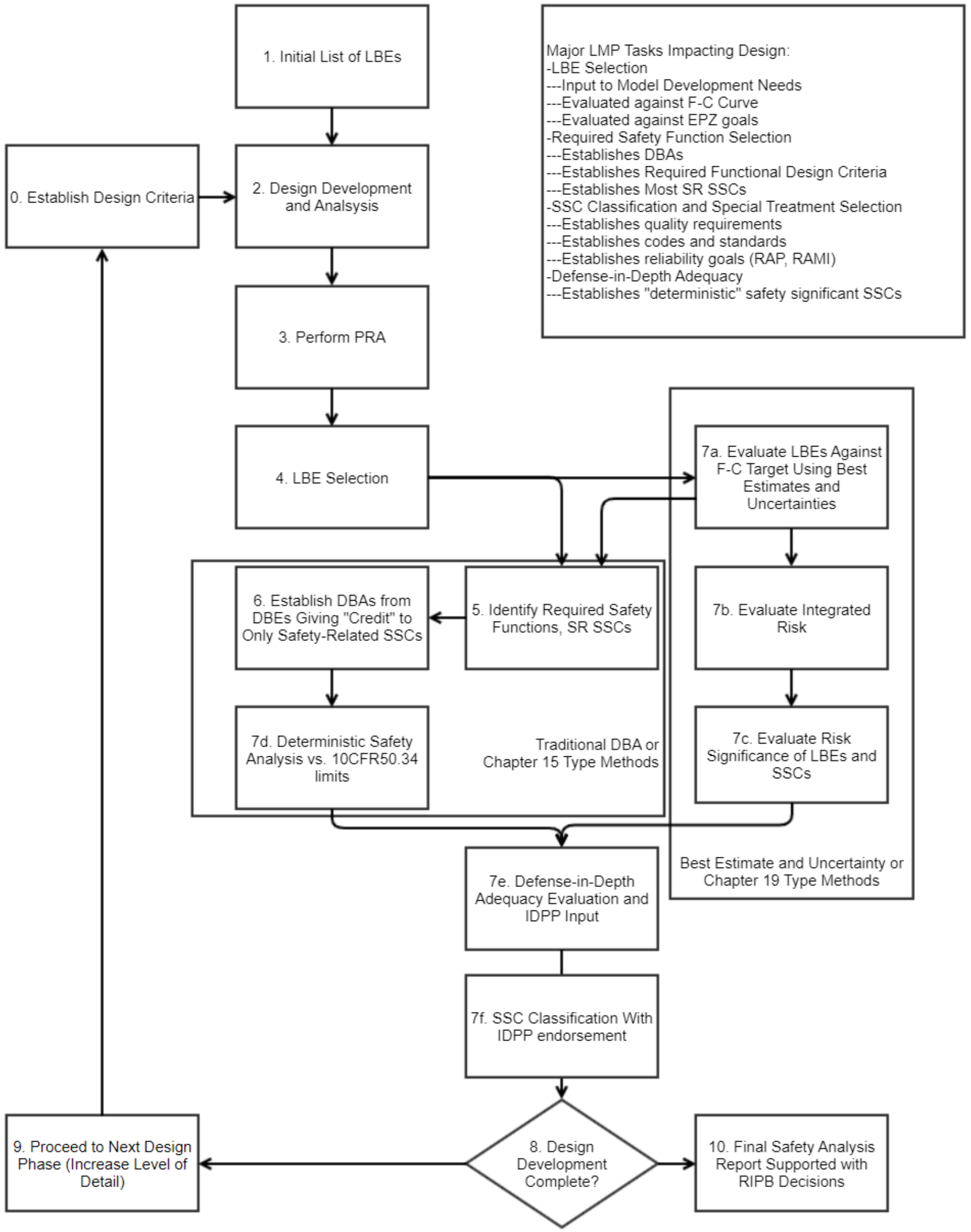
SSC Classification

- PURPOSE - To classify SSCs according to their function. These classifications will determine the codes and quality standards to which the SSC shall be designed, fabricated, erected, and tested.

- SCOPE – Applies to the engineering design efforts of all SSCs.
  - SSCs must be categorized as SR, NSRST, or NST
  - The safety classification of each SSC will be used to determine the level of quality assurance that is required and other special treatment requirements

LMP Process Overview

- Applying NEI 18-04 guidance without exception
- LMP analysis includes LBE selection, SSC classification, and DID evaluation that are part of an integrated process
  - There are direct connections between PRA, LBE selection, faulted events, and deterministic safety analysis that quantify safety functions
  - The IDPP makes the final judgment on SSC classifications taking consideration for any missing scope or limitation in the PRA



LMP Process Overview

- Iterative process
- Using DLs in the Natrium reactor design in Task 2 to meet plant capability DID adequacy check in Task 7e
- Figure adapted from NEI 18-04 Figure 3-2 to clarify design criteria input and IDPP endorsement

SSC Classification Process

- Preliminary SSC classification performed using the results of previous SFR LMP analysis supplemented with engineering judgement and the DL approach

- More detailed classification will occur as the Natrium reactor PRA model improves, allowing for LBEs to be selected

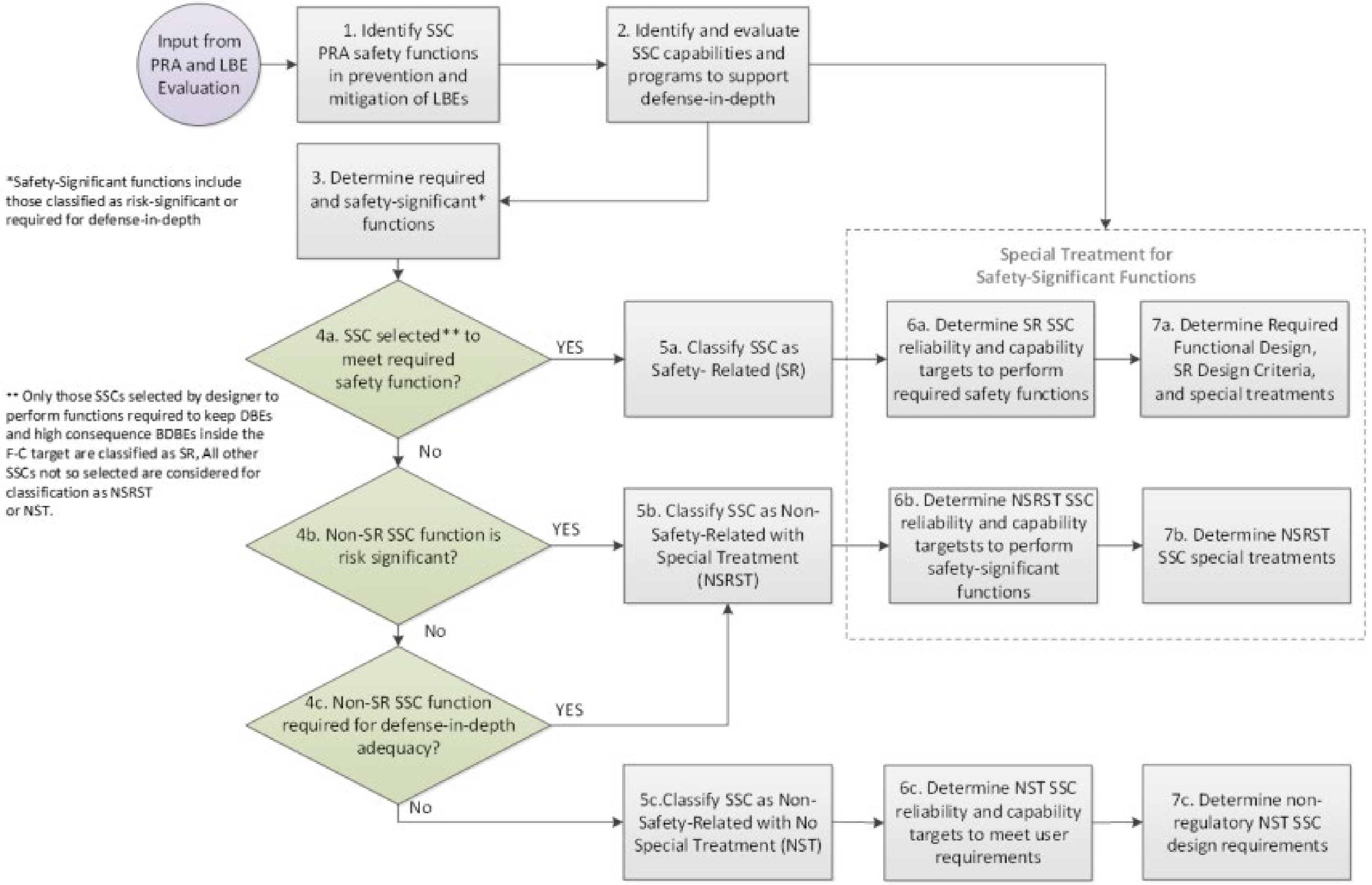


Figure 4-1. SSC Function Safety Classification Process

NEI 18-04

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SSC Classification Process

- **Current work to be completed for PSAR:** Revise the SSC classifications using the Natrium reactor PRA to select LBEs and perform analysis to support DBA selection, RSF identification, SR SSCs, and risk-important NSRST SSCs. DL concept implemented to support initial DID adequacy to be confirmed by IDPP. Determine special treatment requirements to assure adequate performance of SR SSCs.

- **For FSAR:** Confirm adequacy and update LMP analysis if any significant changes are identified for the as-built Natrium reactor.

Safety Functions in LMP

- **Fundamental Safety Functions**: Control, Cool, Contain
- **PRA Safety Functions:** any function that is included in the PRA that may contribute to the prevention or mitigation of a release of radioactive material
- **Required Safety Functions:** those functions that are credited in DBEs, or High Consequence BDBEs to meet the F-C Curve, or DBAs derived from DBEs to meet 10 CFR 50.34 release limits
- **Risk-Significant Safety Function:** a PRA Safety Function that is necessary to keep any LBE inside the F-C Target or is a risk-significant contributor for any of the QHOs.
- **Safety-Significant Function:** a PRA Safety Function that is necessary for DID adequacy or is risk-significant

Safety Function/SSC Classification

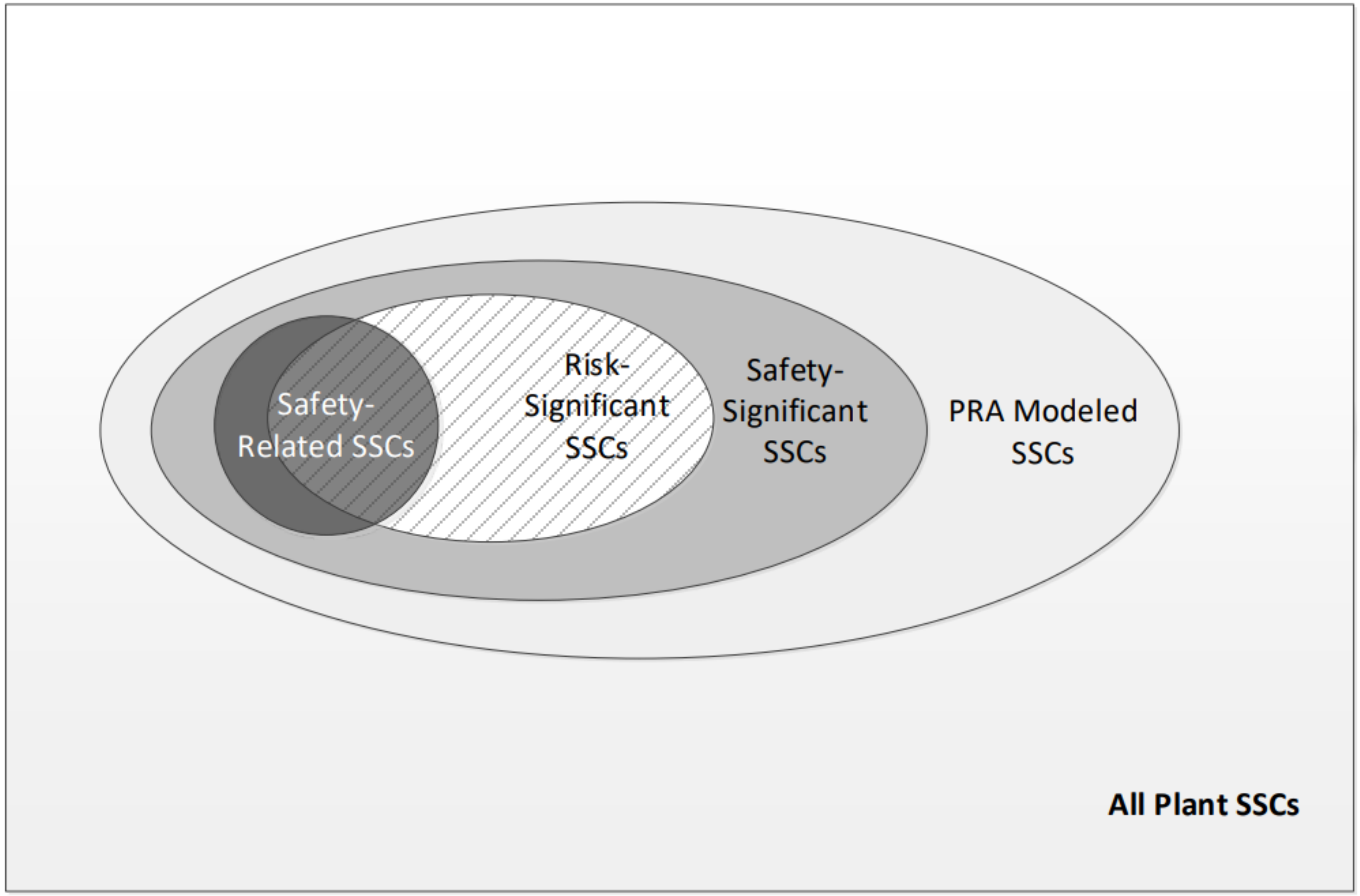


Figure 4-2. Definition of Risk-Significant and Safety-Significant SSCs

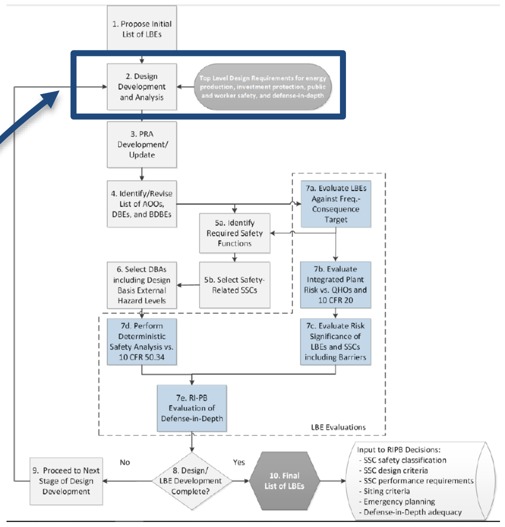
NEI 18-04

Design Application of DID

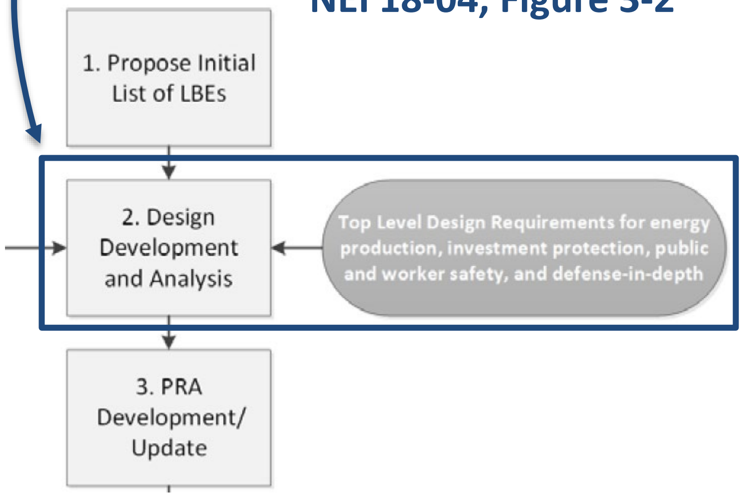
- Design team is applying an explicit DL approach consistent with IAEA SSR-2/1 DL definitions:
  - Identification of mitigating functions for each LBE
  - Assignment of functions to DLs
  - Confirmation of two functional DLs capable of mitigating AOO or most DBE initiating events
  - Application of independence and diversity requirements between functional DLs

- Supports early indications of safety classifications:
  - DL3 functions ‘match’ SR assignment in LMP
  - DL4 functions align with NSRST assignment in LMP but with some expected differences
  - In exceptional cases, a DL2 function may align with NSRST

- This approach is intended to minimize the number of needed design iterations and decreases opportunity for ‘surprises’ when the RIPB Evaluation of DID Adequacy step is performed



NEI 18-04, Figure 3-2



Layers of Defense

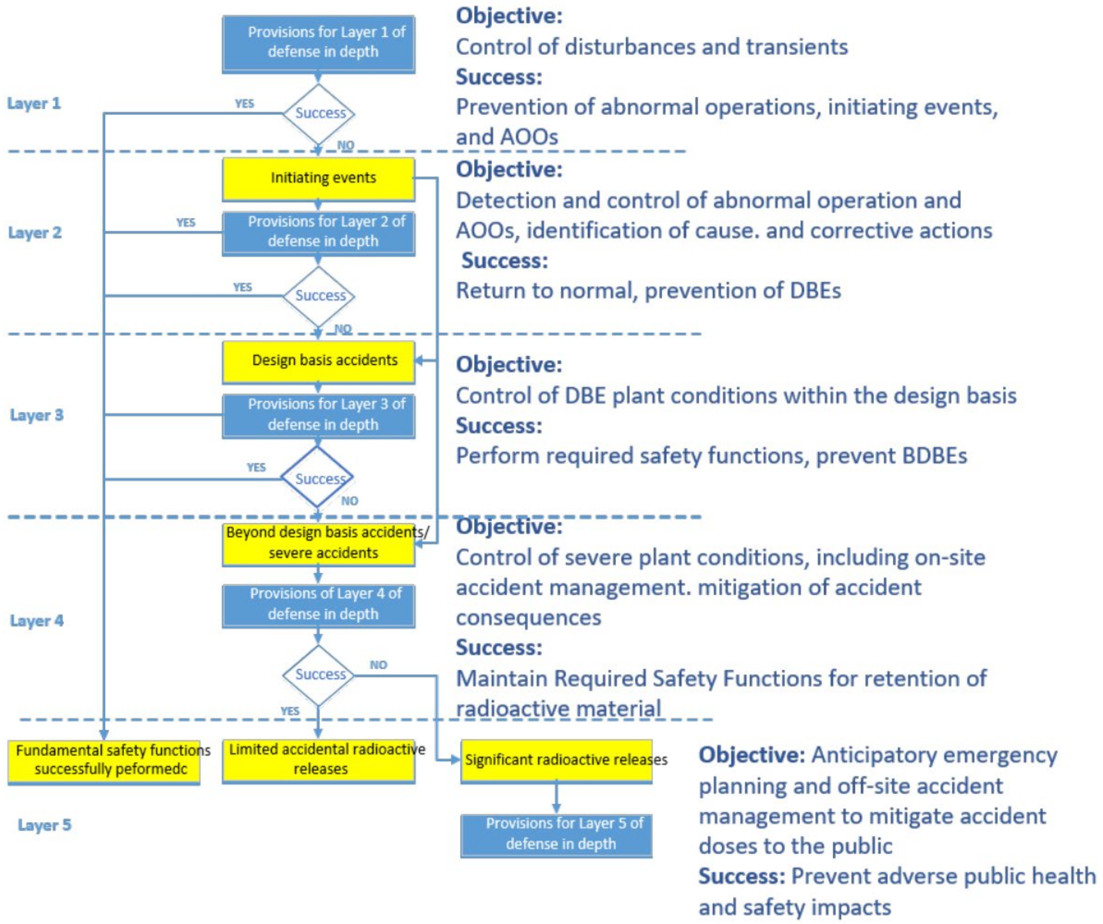


Figure 5-3. Framework for Evaluating LBEs Using Layers of Defense Concept Adapted from IAEA

NEI 18-04

Table 5-2. Guidelines for Establishing the Adequacy of Overall Plant Capability Defense-in-Depth

Layer[a]	Layer Guideline		Overall Guidelines	
	Quantitative	Qualitative	Quantitative	Qualitative
1) Prevent off-normal operation and AOOs	Maintain frequency of plant transients within designed cycles; meet owner requirements for plant reliability and availability[b]		Meet F-C Target for all LBEs and cumulative risk metric targets with sufficient[d] margins	No single design or operational feature,[c] no matter how robust, is exclusively relied upon to satisfy the five layers of defense
2) Control abnormal operation, detect failures, and prevent DBEs	Maintain frequency of all DBEs $< 10^{-2}$/plant-year	Minimize frequency of challenges to SR SSCs		
3) Control DBEs within the analyzed design basis conditions and prevent BDBEs	Maintain frequency of all BDBEs $< 10^{-4}$/plant-year	No single design or operational feature[c] relied upon to meet quantitative objective for all DBEs		
4) Control severe plant conditions and mitigate consequences of BDBEs	Maintain individual risks from all LBEs < QHOs with sufficient[d] margins	No single barrier[c] or plant feature relied upon to limit releases in achieving quantitative objectives for all BDBEs		
5) Deploy adequate offsite protective actions and prevent adverse impact on public health and safety				

Notes:

[a] The plant design and operational features and protective strategies employed to support each layer should be functionally independent.

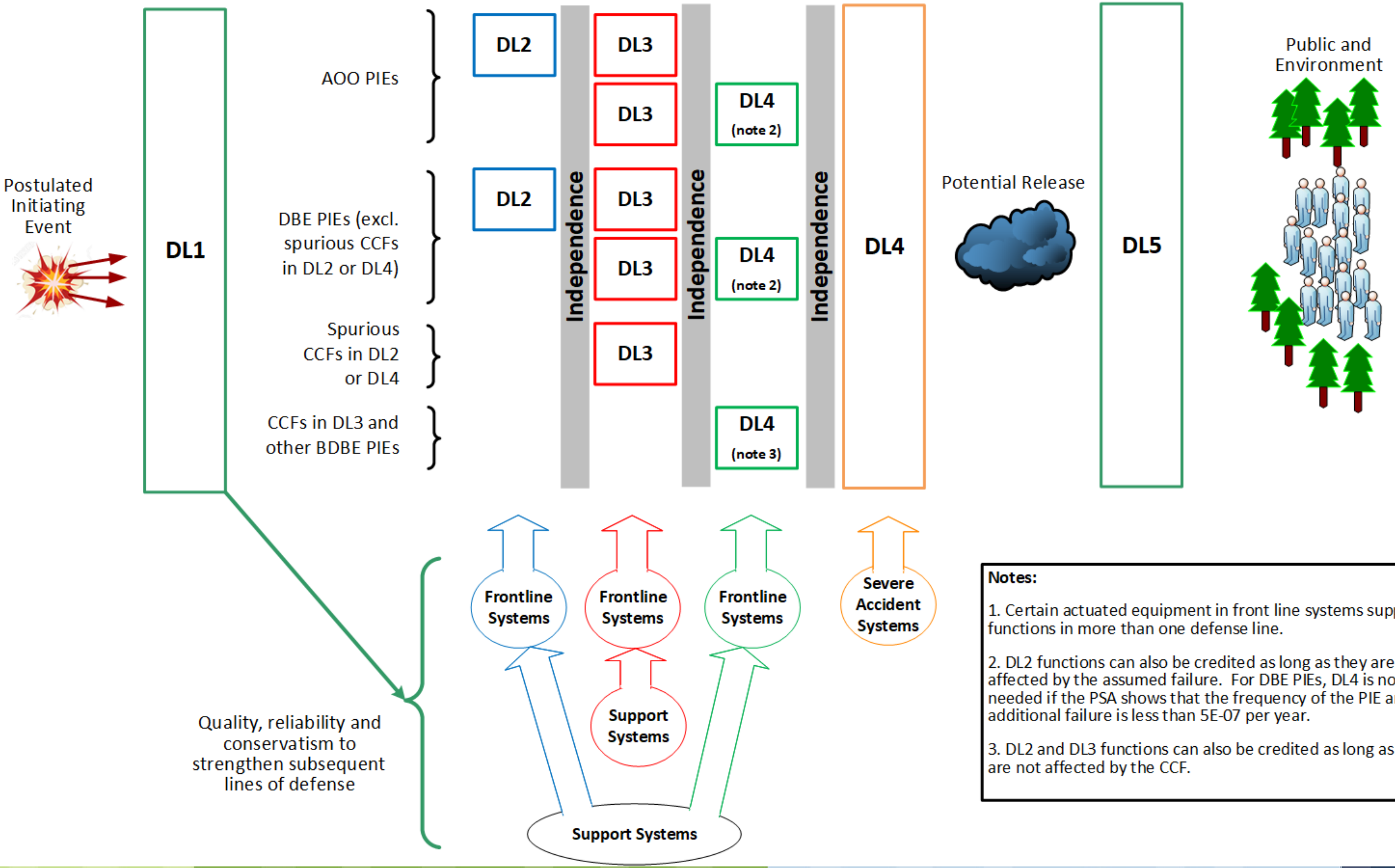
[b] Non-regulatory owner requirements for plant reliability and availability and design targets for transient cycles should limit the frequency of Initiating Events and transients and thereby contribute to the protective strategies for this layer of DID. Quantitative and qualitative targets for these parameters are design specific.

[c] This criterion implies no excessive reliance on programmatic activities or human actions and that at least two independent means are provided to meet this objective.

[d] The level of margins between the LBE risks and the QHOs provides objective evidence of the plant capabilities for DID. Sufficiency will be decided via the IDP.

NEI 18-04

Defense Line Concept



Notes:

1. Certain actuated equipment in front line systems supports functions in more than one defense line.

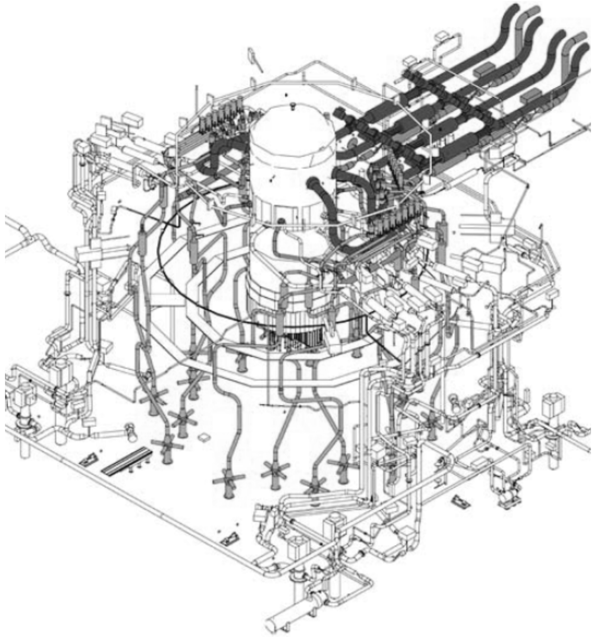
2. DL2 functions can also be credited as long as they are not affected by the assumed failure. For DBE PIEs, DL4 is not needed if the PSA shows that the frequency of the PIE and additional failure is less than 5E-07 per year.

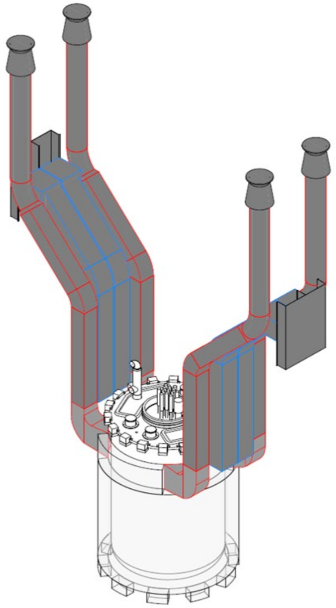
3. DL2 and DL3 functions can also be credited as long as they are not affected by the CCF.

Defense Line Example – Cool Reactor Core

- DL1 is related to programs and features of the design rather than functions
- DL2 is the normal response to most postulated initiating events:
  - Heat removal via IAC in active mode (classified as NST)
- DL3 is typically sufficient for all DBAs/DBEs:
  - Heat removal via RAC (classified as SR)
- DL4 is for BDBEs or simply because further defense is required:
  - Heat removal via IAC in passive mode (classified as NSRST for DID)
- DL5 is related to emergency planning

Simplification of Safety-Related Cooling





LWR Emergency Core Cooling	Natrium Reactor Air Cooling System
• 2600+ ASME Sect. III Pipe Welds	• Zero ASME Sect. III Pipe Welds
• High Pressure Injection (1000+ PSI)	• Atmospheric Pressure (<1 PSI)
• Large Water Inventory Requirements	• Unlimited Air-Cooled Heat Sink Supply
• Active Valve and Pump Operation	• Fully Passive (Always in Operation)
• Multiple Trains and Sub-systems	• Singular Rugged System

IDPP review to ensure:

- Scope of PRA is sufficiently complete
- LBEs and SSCs identified adequately
- Basis of RSF selection is sound
- SR SSCs can perform RSFs appropriately
- Protective measures for risk-significant LBEs are well understood
- Protective measures against CCF are identified
- Any available risk benefit is characterized, e.g. sensitivity studies, to determine if more margin can be achieved easily

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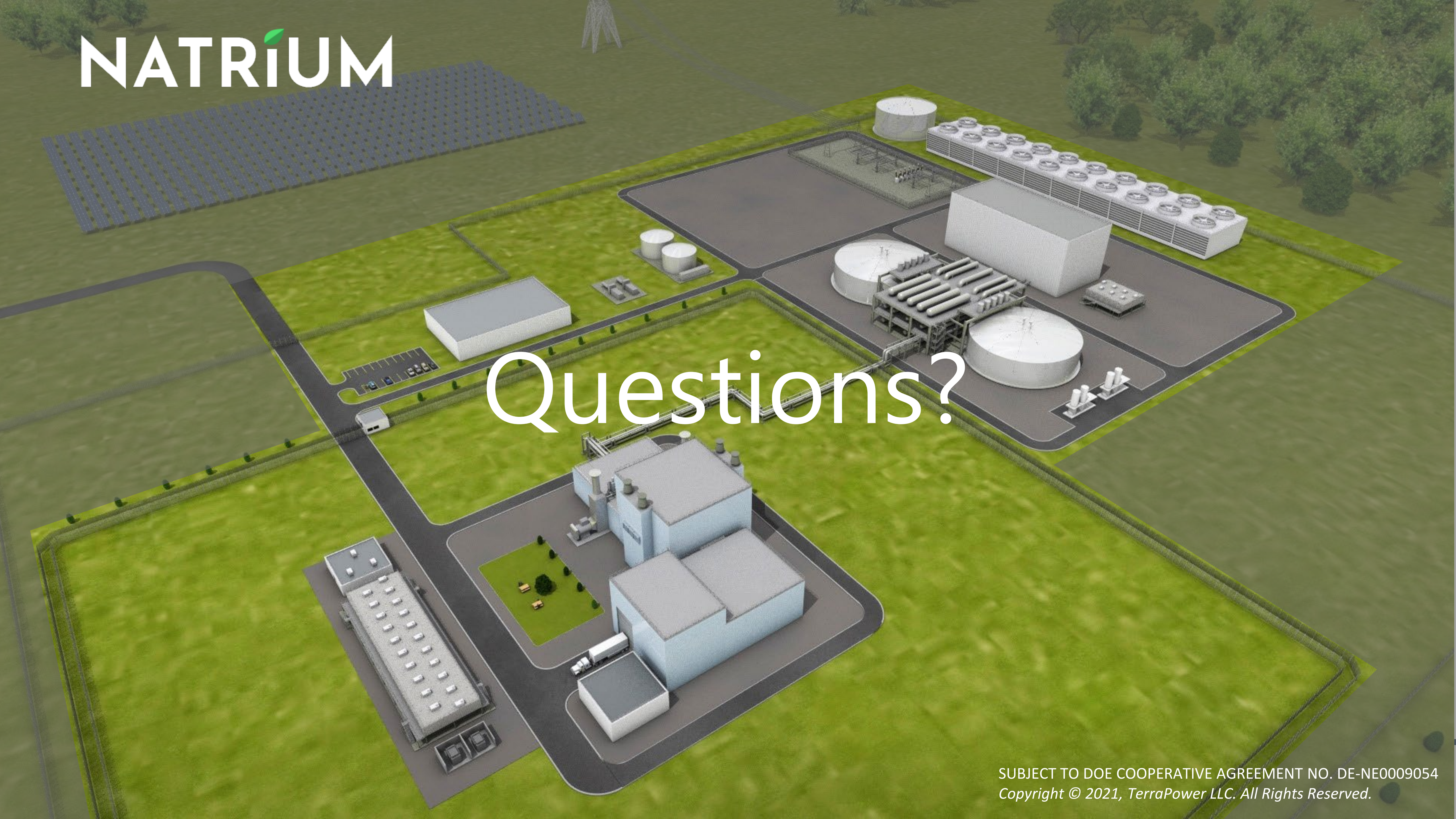

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Questions?

Acronym List

AC – Alternating Current
AOO – Anticipated Operational Occurrence
ASME – American Society of Mechanical Engineers
BDBE – Beyond Design Basis Event
CCF – Common-Cause Failure
CFR – Code of Federal Regulations
DBA – Design Basis Accident
DBE – Design Basis Event
DID – Defense-in-Depth
DL – Defense Line
EBR – Experimental Breeder Reactor
F-C – Frequency-Consequence
FFTF – Fast Flux Test Facility
FSAR – Final Safety Analysis Report
HX – Heat Exchanger
IAC – Intermediate Air Cooling
IAEA – International Atomic Energy Agency
IDPP – Integrated Decision-Making Process Panel
LBE – Licensing Basis Event
LMP – Licensing Modernization Project
NEI – Nuclear Energy Institute
NI – Nuclear Island
NSRST – Non-Safety-Related with Special Treatment
NST – Non-Safety-Related with No Special Treatment
PIE – Postulated Initiating Event
PRA – Probabilistic Risk Assessment
PSAR – Preliminary Safety Analysis Report
PSI – Pounds Per Square Inch
QHO – Quantitative Health Objective
RAC – Reactor Air Cooling
RIPB – Risk-Informed, Performance-Based
RSF – Required Safety Function
SFR – Sodium Fast Reactor
SR – Safety-Related
SSC – Structures, Systems, and Components
TREAT – Transient Reactor Test