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Main Control Room Habitability Strategy

a TerraPower & GE-Hitachi technology

TP-LIC-PRSNT-0013

SUBJECT TO DOE COOPERATIVE AGREEMENT NO. DE-NE0009054

Agenda

- Natrium™ reactor overview
- MCR regulatory basis:
  - PDC 19
  - Additional insights and regulatory guidance
  - Other PDCs and regulations
  - Prior applications
- Habitability strategy
  - Snapshot
  - Differences with respect to prior applications
- Remote shutdown facility
- MCR envelope and Remote Shutdown Complex location
- MCR and Remote Shutdown Complex safety classification
- HVAC design (MCR Remote and Shutdown Complex)
- Radiological Consequence Analysis

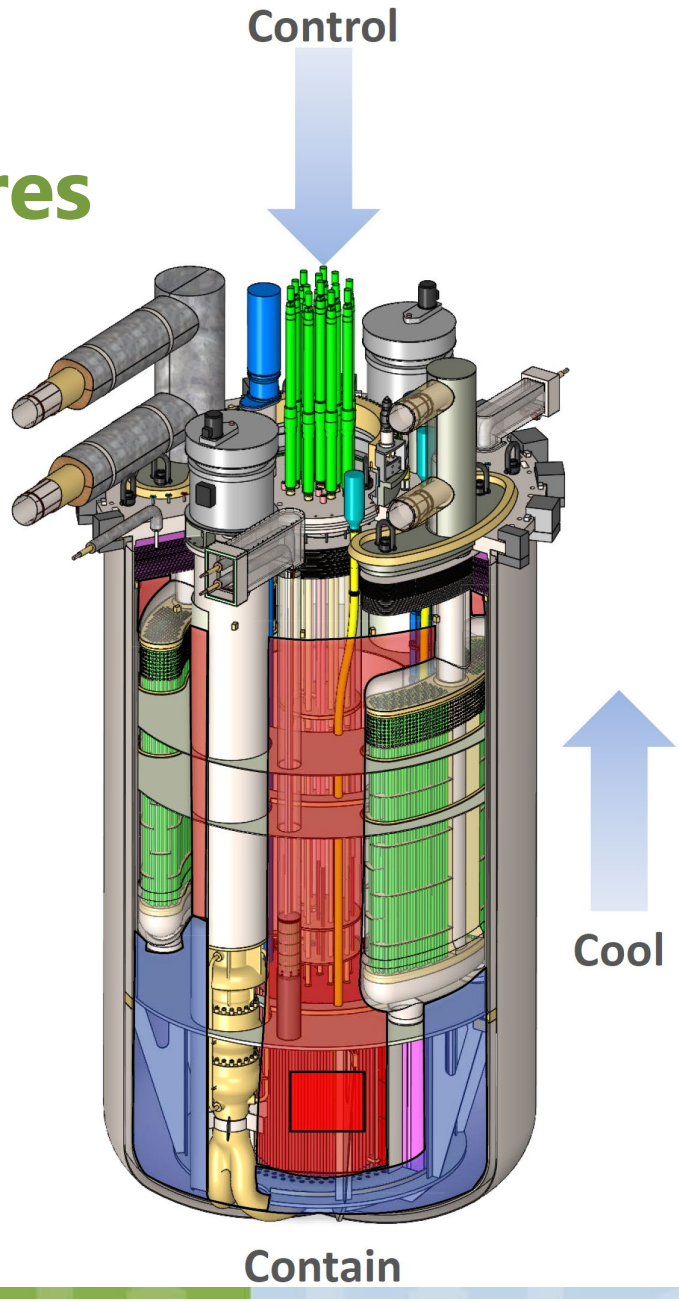
Natrium Reactor Overview

- 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

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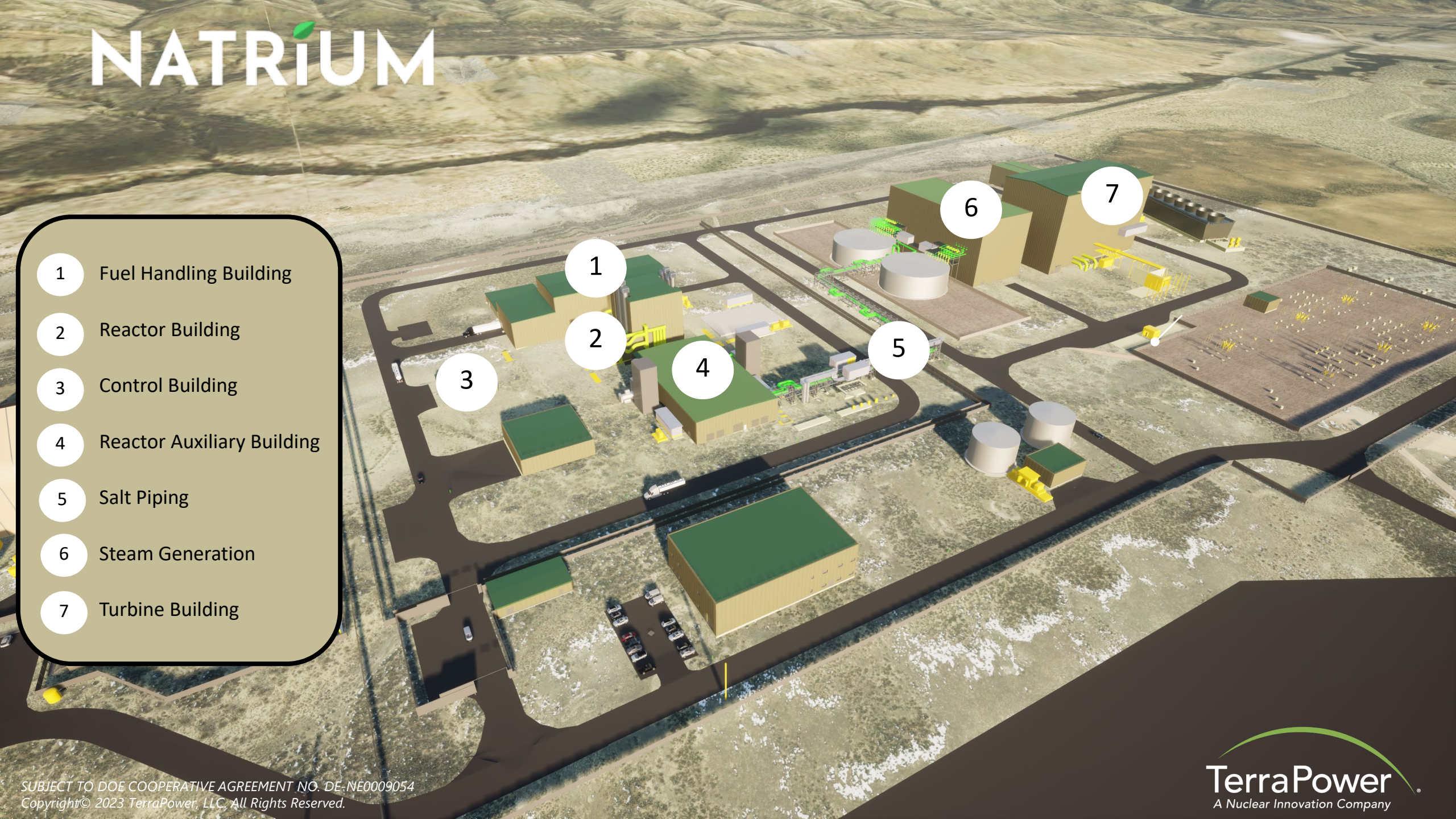

1. Fuel Handling Building
2. Reactor Building
3. Control Building
4. Reactor Auxiliary Building
5. Salt Piping
6. Steam Generation
7. Turbine Building

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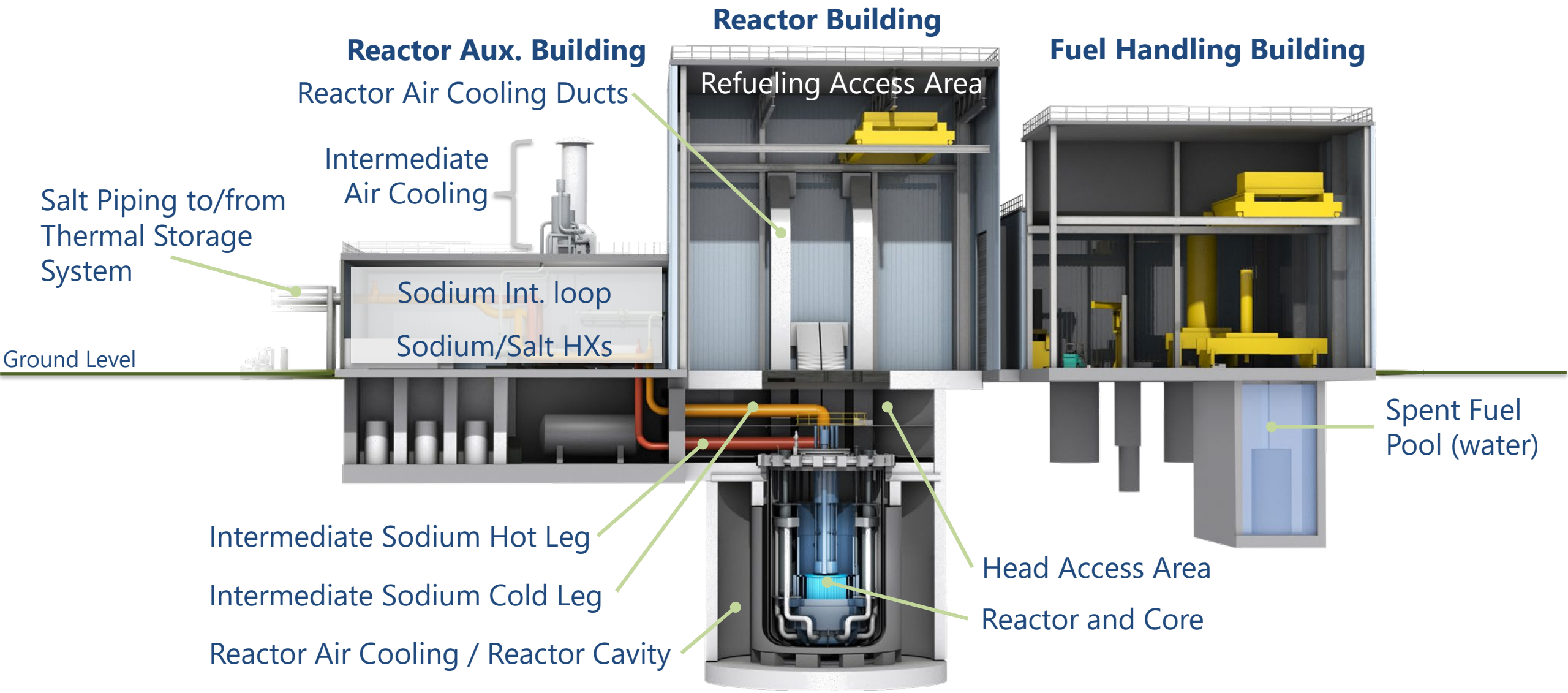

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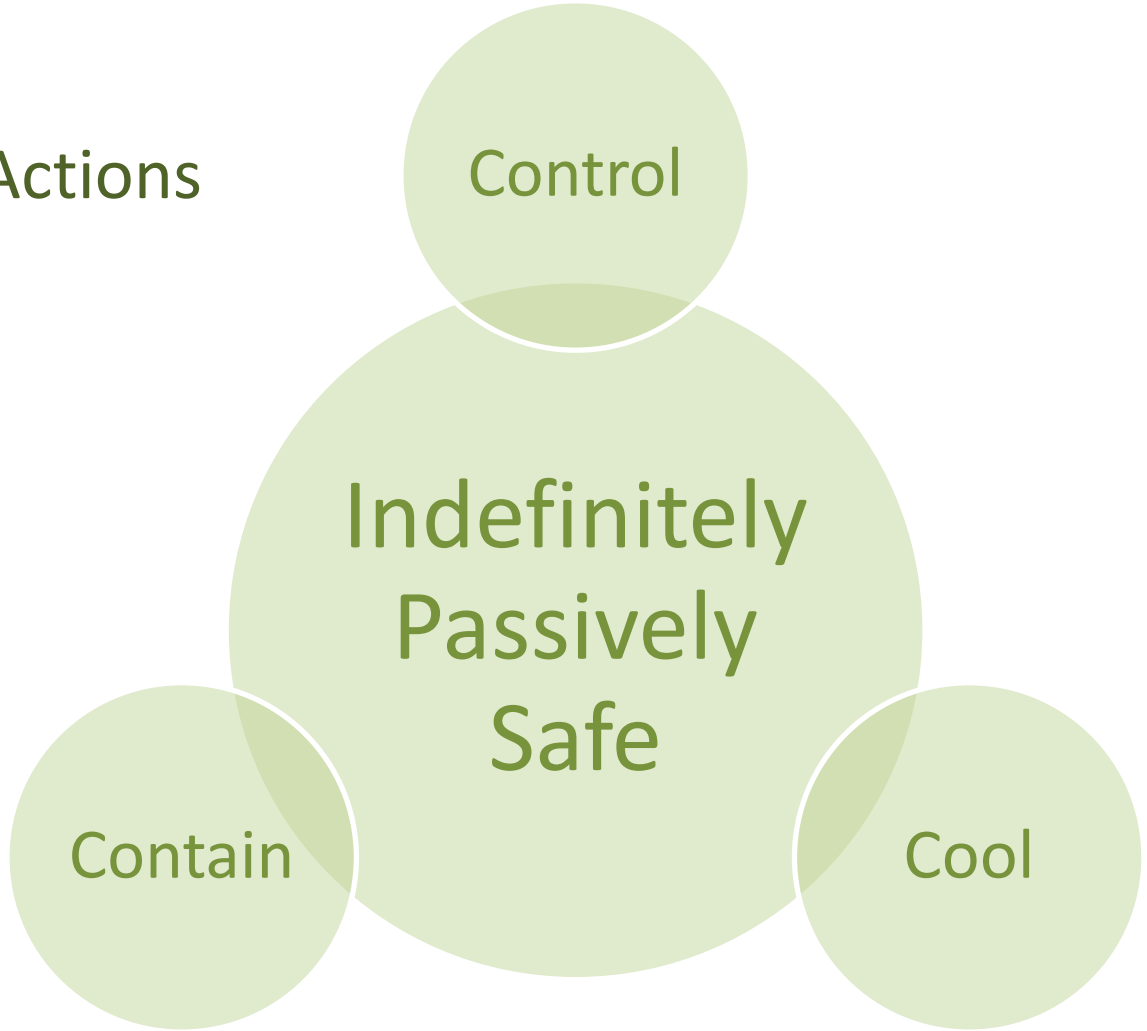
Strategy and Areas for Feedback

- Integrated MCR Habitability strategy to meet PDC 19

- Specific areas for NRC feedback
  - Remote shutdown facility strategy
  - Application of Kairos as precedent
  - NSRST MCR

- No SR Operator Actions
- MCR NSRST



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MCR Habitability Regulatory Bases

Regulatory Bases for MCR Habitability

PDC 19

A control room shall be provided from which actions can be taken to operate the nuclear power unit safely under normal conditions and to maintain it in a safe condition under accident conditions. Adequate radiation protection shall be provided to permit access and occupancy of the control room under accident conditions without personnel receiving radiation exposures in excess of 5 rem total effective dose equivalent, as defined in § 50.2 for the duration of the accident.

Adequate habitability measures shall be provided to permit access and occupancy of the control room during normal operations and under accident conditions.

Adequate protection against sodium aerosols shall be provided to permit access and occupancy of the control room under accident conditions.

Equipment at appropriate locations outside the control room shall be provided (1) with a design capability for prompt shutdown of the reactor, including necessary instrumentation and controls to maintain the unit in a safe condition during shutdown, and (2) with a potential capability for subsequent safe shutdown of the reactor through the use of suitable procedures.

As submitted in TerraPower Topical Report, NATD-LIC-RPRT-0002 Revision 0, *Principal Design Criteria for the Natrium Advanced Reactor*, dated January 24, 2023 (ADAMS Accession No. ML23024A281). Based on Regulatory Guide 1.232, Revision 0, Appendix B, Sodium-cooled Fast Reactor Design Criteria

(emphasis added)

Additional Insights for PDC 19 - Regulatory Guidance

Document No.	Description	Insights
SRP 6.4 R3 SRP 9.4.1 Revision 3	Control Room Area Ventilation System	Radiation, combustion, toxic chemicals, coincident LOOP, ambient temperature control, CO_2, detection and isolation, PDC 2, and PDC 4.
RG 1.29 Revision 6	Seismic Design Classification for Nuclear Power Plants	Seismic Interaction - prevent incapacitating injury to occupants of the control room
RG 1.189 Revision 4	Fire Protection for Nuclear Power Plants	Post-fire safe shutdown, alternative and dedicated shutdown capability, loss of offsite power/SBO, control room complex, control room ventilation
RG 1.196 Revision 1	Control Room Habitability at Light-Water Nuclear Power Reactors	Radiation and toxic chemical protection
RG 1.78 Revision 2	Evaluating the Habitability of a Nuclear Power Plant Control Room During a Postulated Hazardous Chemical Release	Toxic chemical protection

Additional Considerations - Other PDCs and Regulations		
Document No.	**Description**	**Requirements**
PDC 2	Design bases for protection against natural phenomena	Protect equipment from natural phenomena events commensurate with safety-significance of SSC
PDC 3	Fire protection	Protect equipment from fires commensurate with safety-significance of SSC
PDC 4	Environmental and dynamic effects design bases	Protect equipment from environmental and dynamic effects commensurate with safety-significance of SSC
10 CFR 73	Physical security	Provide protection against bullets and the Design Basis Threat
10 CFR 50.155	Mitigation of beyond-design-basis events	Provide ability to respond after Beyond Design Basis Events
10 CFR 50.150	Aircraft impact assessment	Provide ability to respond after Beyond Design Basis Aircraft Impact

Prior Applications

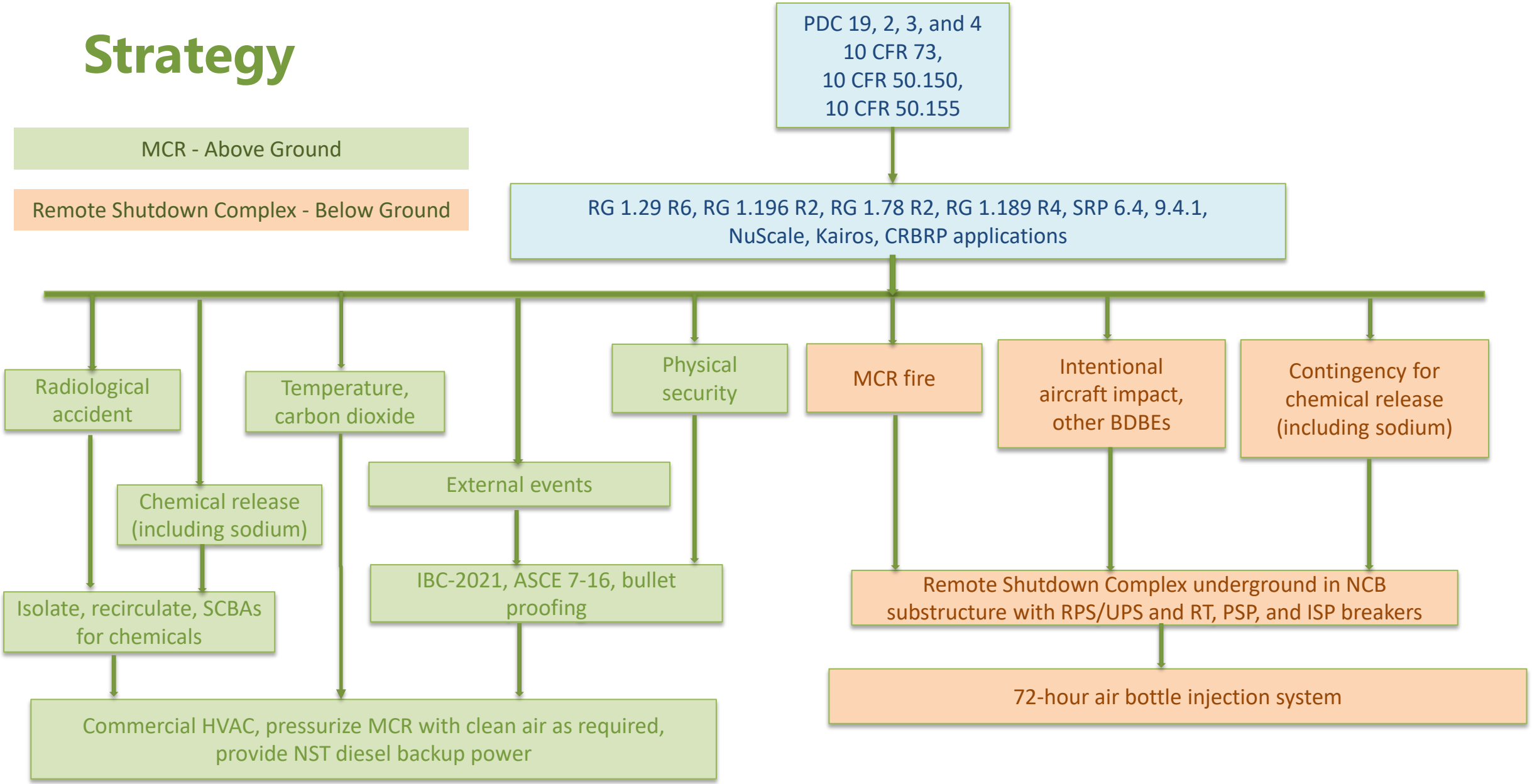
Document No.	Description	Insights
ML23158A268	Safety Evaluation Related to the Kairos Power LLC Construction Permit Application for the Hermes Test Reactor	SER Section 3.5, 7.4.3, 9.4.3.3, 13.2.1.3: Hermes PSAR Section 7.4.3.1 states "the MCR and Auxiliary Building that houses the MCR are designed to local building code standards." Per Hermes PSAR Section 3.5, the MCR is considered NSRST and per Section 3.4.2, the codes employed are IBC-2012 and ASCE/SEI 7-10. The "MCR is located at a distance from the reactor building such that the radiological consequences of unfiltered air in the MCR during postulated events does not exceed 5 rem total effective dose equivalent for the duration of the event."
ML20205L406, ML20023A318	NuScale Design Certification Final Safety Evaluation Report, Chapter 6 – Engineered Safety Features	Section 6.4.4.2 - MCR isolated and bottle air injection and relief used to provide habitability for 72 hours mission time. Auto and manual valves provided.
NUREG-0968, Vol 1	Safety Evaluation Report Related to Construction of Clinch River Breeder Reactor Plant (ML082381008)	Section 6.3.1 - MCR leakage ~ 0.06 air changes per hour. Section 6.3.2 - MCR isolation and recirculation employed to address sodium aerosols Section 6.3.3 - Deliver non-radioactive air to MCR to pressurize the control room to a minimum of 1/8 inch water column.

MCR Habitability Strategy

Strategy

MCR - Above Ground

Remote Shutdown Complex - Below Ground



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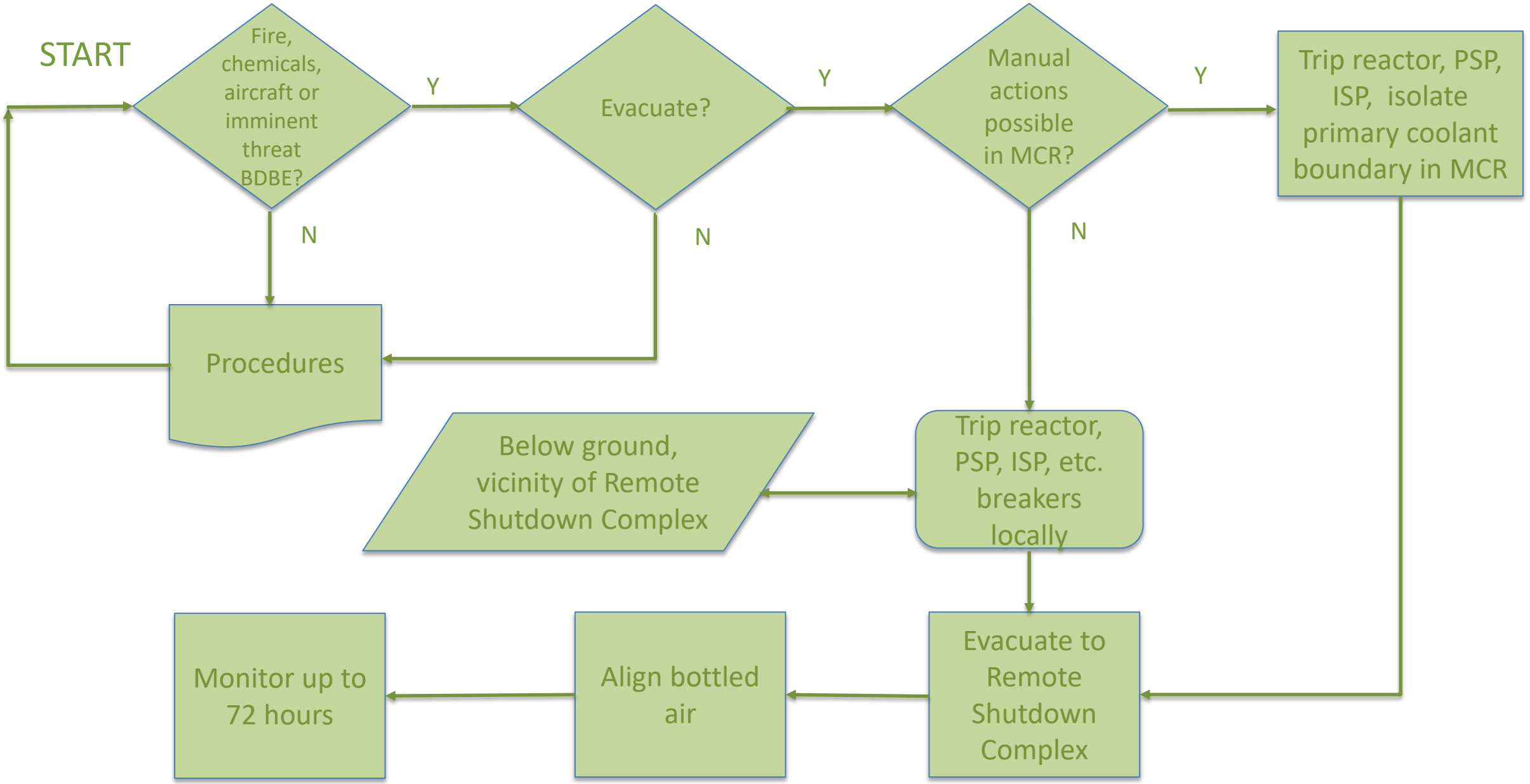
Differences with Respect to Prior Applications

Item	Design strategy	Difference with respect to prior applications	Bases for difference
Ambient Temperature/CO2 Control	MCR – Commercial HVAC. Remote Shutdown Complex – Passive heat sinks, bottled air.	None	
Combustion (Fire and Smoke)	MCR – Isolate, evacuate to Remote Shutdown Complex. Remote Shutdown Complex – Bottled air as needed.	None	
Radiation	MCR – Isolate, recirculate, use outside air to pressurize MCR. Remote Shutdown Complex – Bottled air. Only for BDBEs.	Multiple barriers (functional containment) and mechanistic source term expected to minimize radionuclide migration to the MCR.	NST FHB HEPA filters will reduce doses to acceptable levels.
Coincident Loss of Offsite Power	MCR – HVAC powered from backup diesels. Remote Shutdown Complex – Bottled air. Only for BDBEs or DBH contingencies.	None – Backup diesels are NST. Potential loss of offsite power and diesels during seismic or tornado events to be addressed with passive cooling, temporary cooling procedures, and/or evacuation to Remote Shutdown Complex	.

Differences with Respect to Prior Applications (continued)

Item	Design strategy	Difference with respect to prior applications	Bases for difference
Detection and Isolation	MCR – Isolates and recirculates upon detection of radiation or sodium aerosols. Employ HazMat and SCBAs or evacuate as needed for chemicals. Remote Shutdown Complex – Isolate normal HVAC. Manually align bottled air.	Remote Shutdown Complex bottled air manually aligned.	MCR monitoring will provide sufficient time to manually align Remote Shutdown Complex air.
PDC 2	ASCE 7-16 and IBC-2021	Kairos applied IBC-2012 and ASCE 7-10	IBC-2021 consistent with state of Wyoming. ASCE 7-16 consistent other uses for Kemmerer Unit 1.
PDC 3	Fire detection and suppression provided in MCR. Combustibles limited.	None	
PDC 4	MCR located sufficient distance from other NI SSCs to prevent dynamic effects that could otherwise occur.	None	
10 CFR 73	MCR will be bullet protected and otherwise designed for DBT	None	
10 CFR 50.150 10 CFR 50.155	MCR will be evacuated to Remote Shutdown Complex for BDBEs if required	None	

Remote Shutdown Complex



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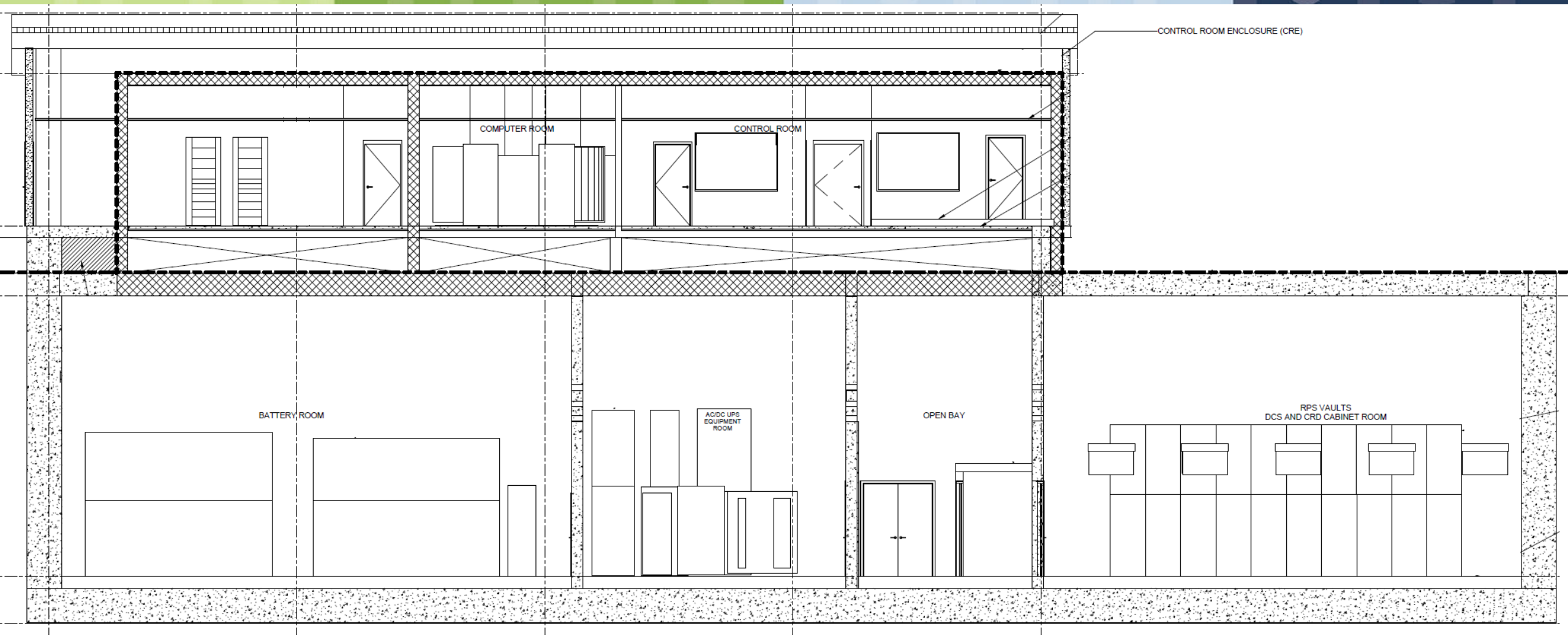
MCR Envelope
and
Remote Shutdown Complex Location

MCR Envelope and Remote Shutdown Complex Location

- MCR envelope defined consistent with Regulatory Guide 1.196
  - MCR
  - Computer room
  - Shift Manager's office
  - Security vestibule entrance to the MCR.
  - Restroom and kitchen

NCB Cross-Section



NOTE: Drawings subject to change as design evolves.

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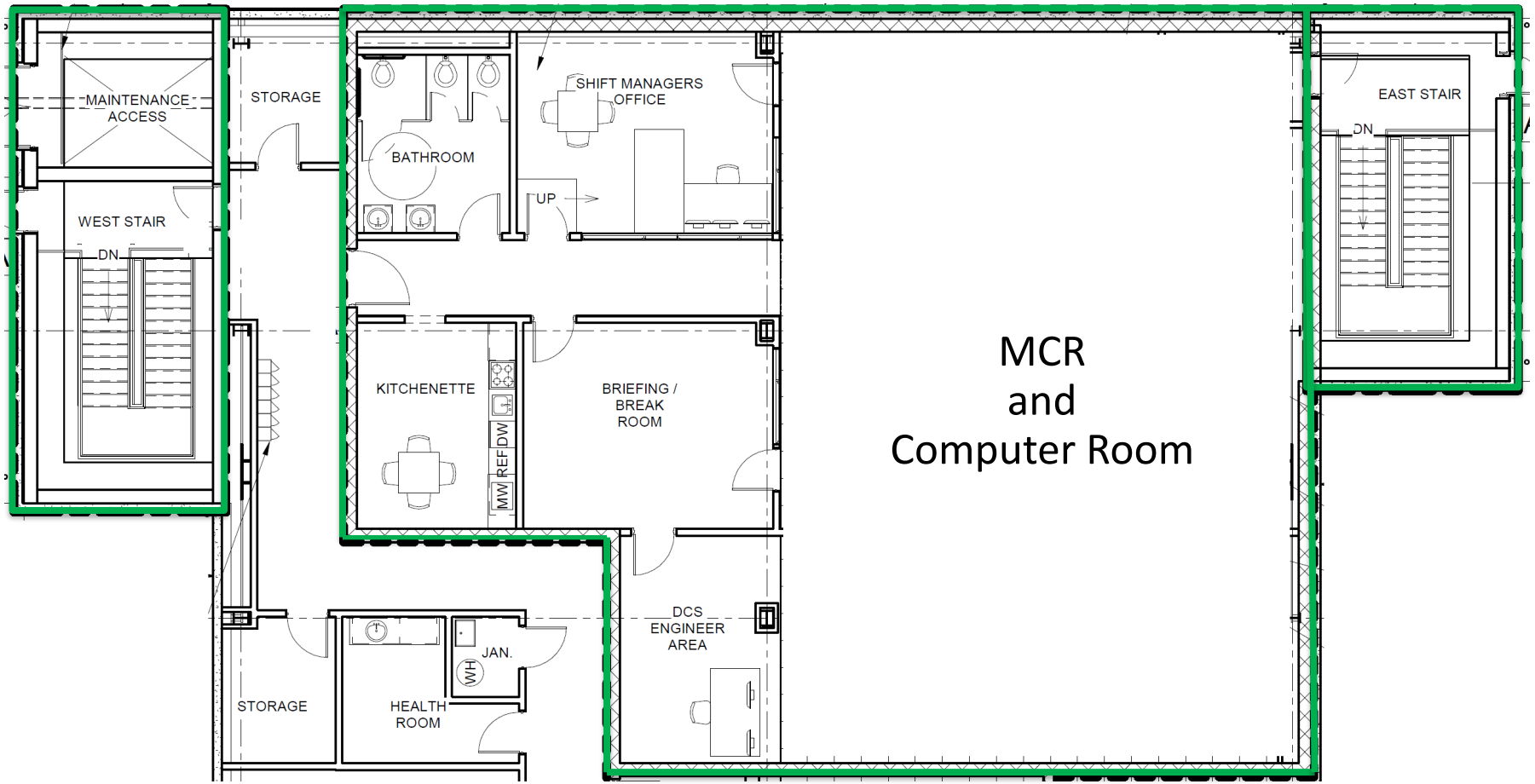
NCB Planview – Superstructure

MCR Envelope



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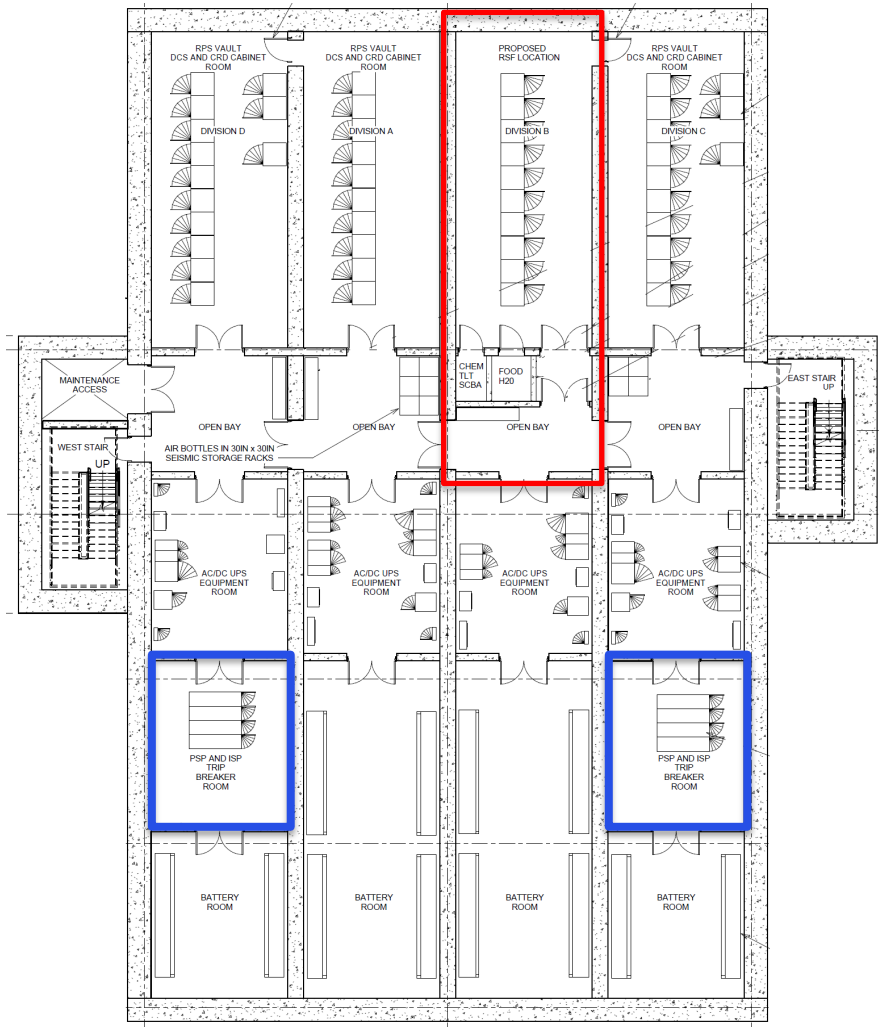
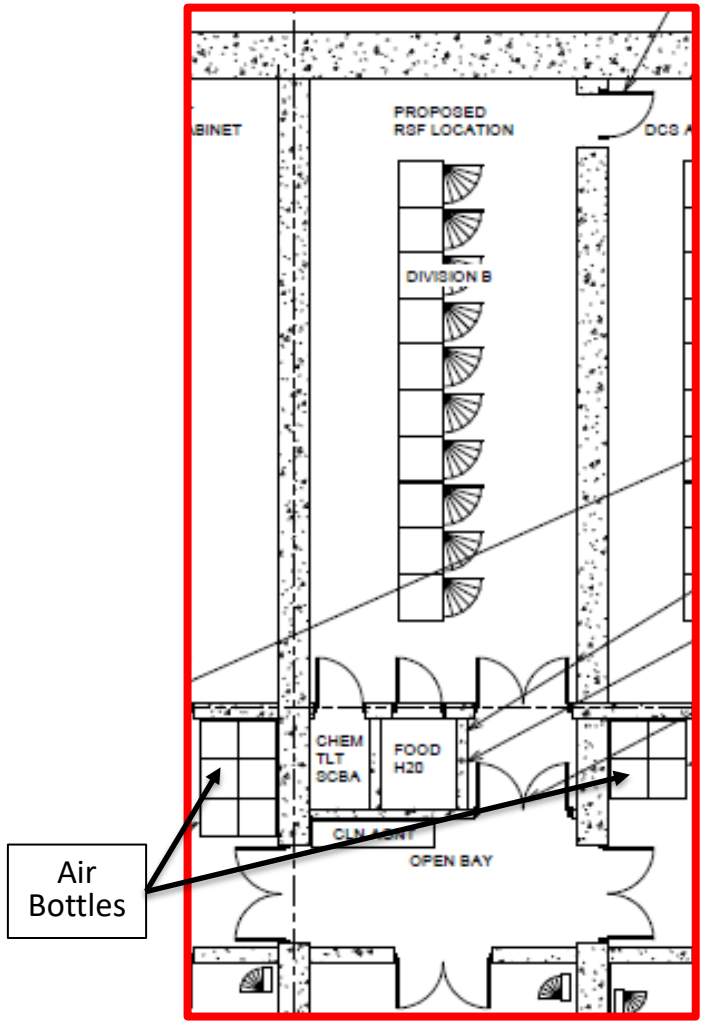
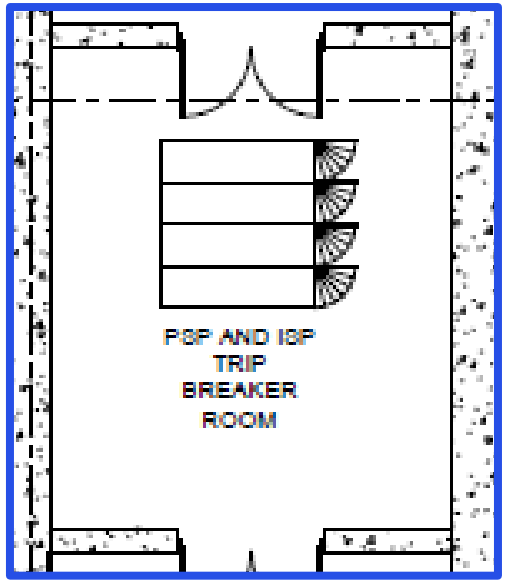
NCB Planview – Substructure







NOTE: Drawings subject to change as design evolves.

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MCR and Remote Shutdown Complex Safety Classification

Functions Associated with MCR and Remote Shutdown Complex

MCR

- Manual actuation of RPS functions (e.g., manual scram) (NSRST)
- Manual Shutdown for Off-Normal Conditions (NST)
- Manual Primary and Intermediate Pump Trip (NST)
- Manual Isolation of Primary Coolant Boundary (NST)

Remote Shutdown Complex

- Manual actuation of RPS functions (e.g., manual scram) (NSRST)
- Post Accident Monitoring (NSRST)

No LBEs require these functions to succeed to remain within the F-C target

MCR Safety Classification

- All SR actions are accomplished passively
  - No operator actions required for DBAs
- SR functions are normally automatically actuated by RPS or failsafe
- SSC Classification of manual actuations of SR functions of RPS is NSRST
  - Neither risk-significant nor initial plant capability DID safety-significant
  - Based on the standards applied and engineering judgment NSRST classification is applied to manual control of the SR RPS functions
  - IEEE 603-1991, Clause 6.2 "Manual Control." The special treatment includes qualifications of the manual controls per environmental qualification standard IEEE 323-1974 and seismic qualification standard IEEE 344-2006, along with providing electrical isolation between the NSRST manual controls and any SR RPS component.

Remote Shutdown Complex Safety Classification

- The Remote Shutdown Complex location provides backup manual actuation of SR function of RPS using nearby local trip switches.
- The Remote Shutdown Panel, located within the Remote Shutdown Complex, will have capability for monitoring to serve the purpose of supporting PAM (NSRST).
  - Coping time for the Remote Shutdown Complex subsequent to an external event is 72 hours. This time is consistent with the coping time in Regulatory Guide 1.189 Revision 4, “Fire Protection for Nuclear Power Plants” and prior applications.

Structure Safety Classification

- Structure classifications are based on the systems physically supported.
- Above grade portion is NSRST and is associated with the functions of the MCR that it provides physical support for.
- Below grade portion is SR and is associated with the functions of the RPS.
  - SR NCB substructure provides physical support for NSRST Remote Shutdown Complex.

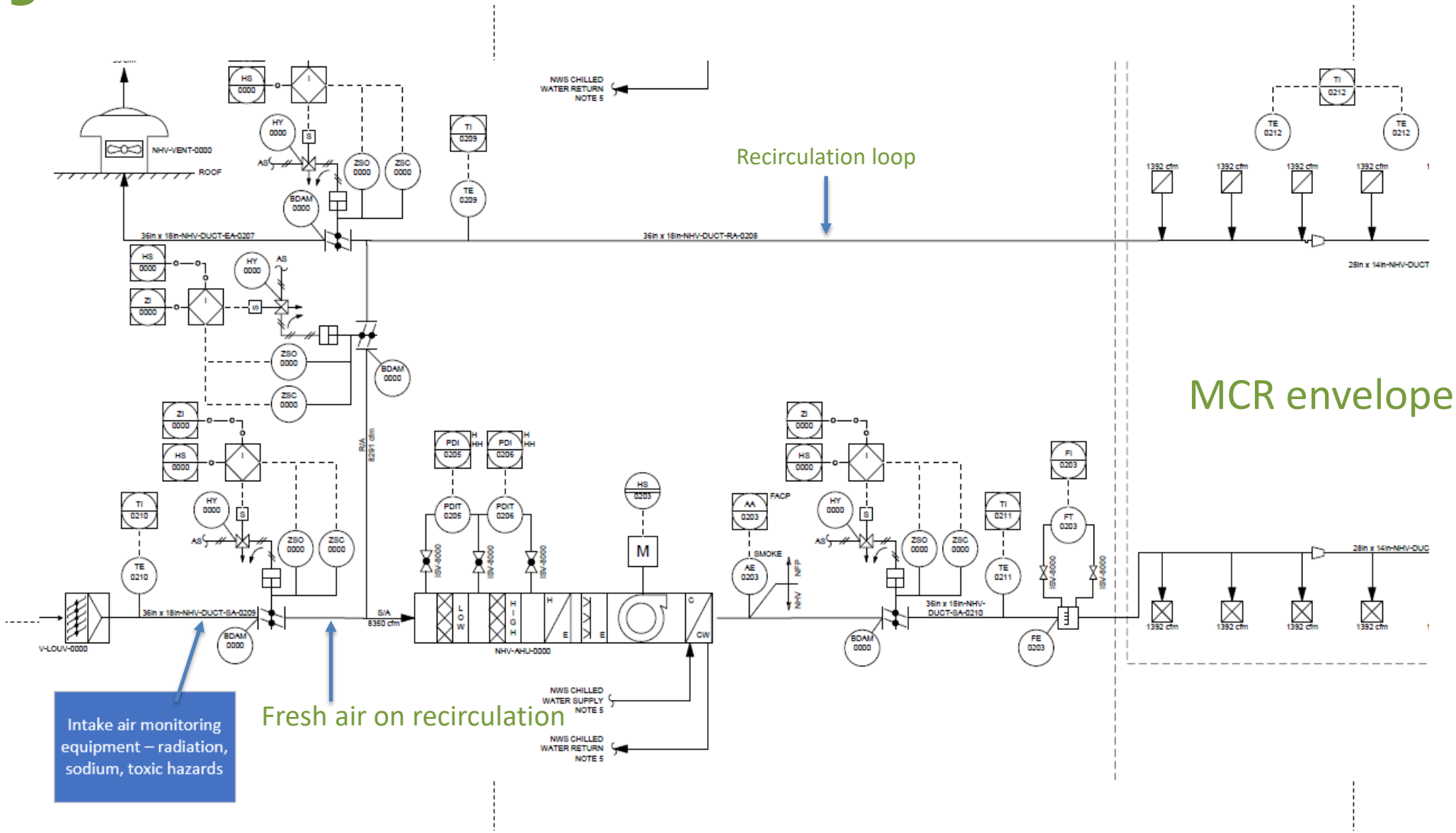
HVAC Design

HVAC Design

- MCR HVAC
  - Fresh air intake monitors for radiation, sodium, and identified toxic hazards to indicate need for recirculation mode.
  - Positive pressure in the MCR envelope maintained for all operating modes with two 50% units.
- RPS/XIS Facility HVAC (proposed Remote Shutdown Complex location)
  - Supply and return ducts are isolated when MCR envelope units enter recirculation mode.
  - Passive cooling for accident sequences.
  - Bottle air manually aligned for positive pressurization of Remote Shutdown Complex.

HVAC Design

Two 50% Trains



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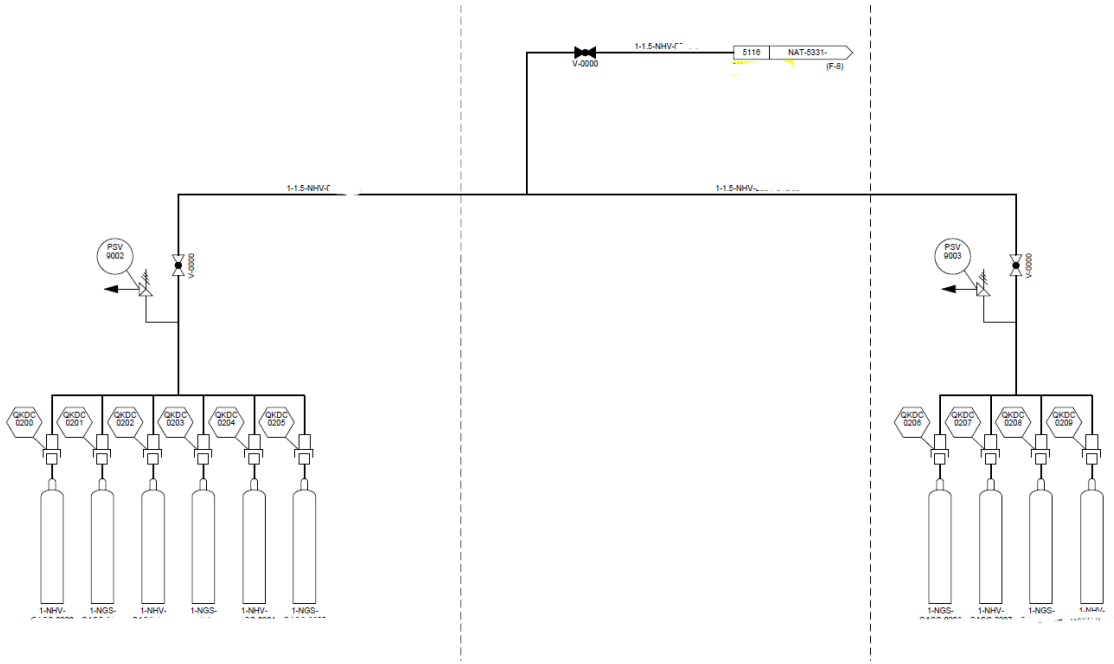
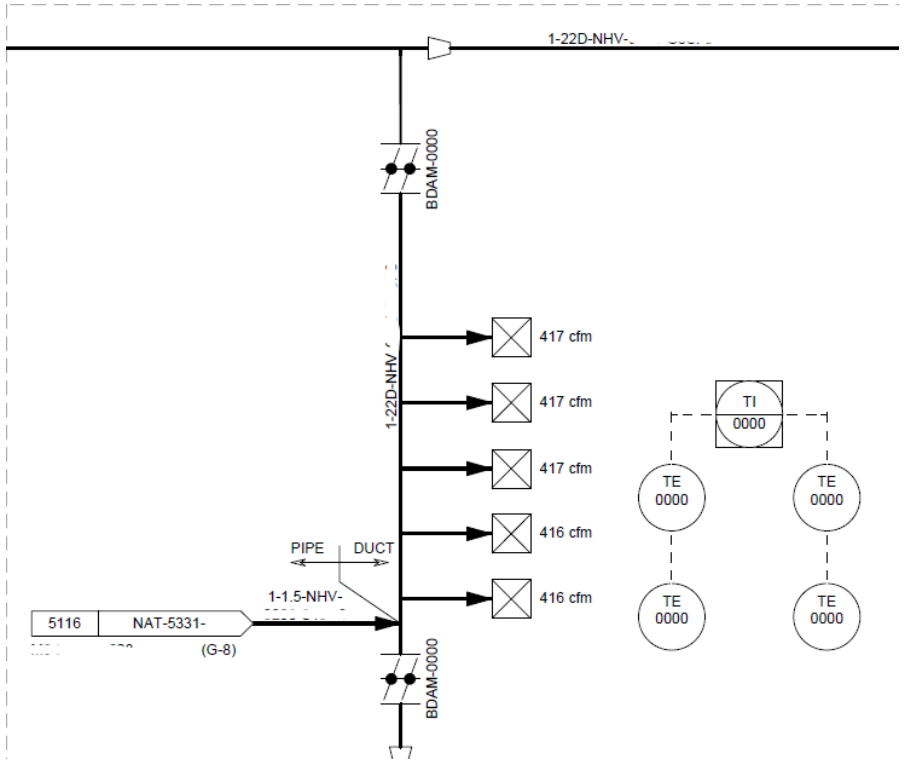
Remote Shutdown Complex Bottles To Duct





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Radiological Consequences of Postulated Accidents

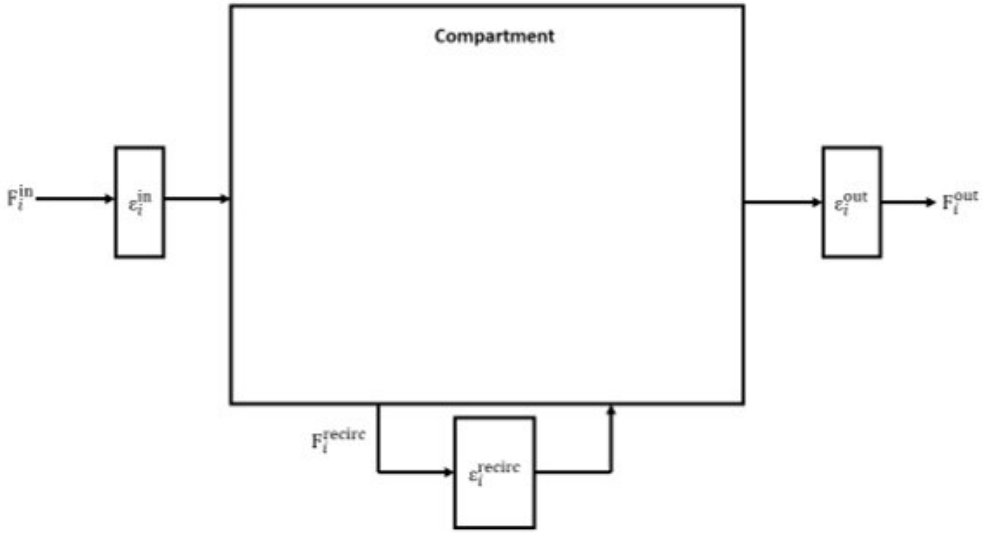
Source Term and Radiological Consequences Method Overview

	AOOs, DBEs, BDBEs with release	DBAs with Release
Mechanistic Source Term	Credit for reasonably available SSCs and removal mechanisms.	Credit SR SSC barriers (design leakage). Conservative assumptions for removal mechanisms.
Atmospheric Dispersion	Calculated from weather trial data in WinMACCS.	Use enveloping χ/Q factors.
Dose Assessment	EAB 30-day TEDE doses w/ uncertainty plotted on F-C target curve.	EAB/LPZ Dose -> 10 CFR 50.34 **MCR Dose -> PDC 19***

*Natrium Control Room doses are initially assessed using bounding/conservative treatment under the DBA Radiological Consequence Methodology .

DBA Analysis Method – Control Room Receptor

- MCR envelope represented by single compartment exchanging air with the environment.
- Gains to MCR radionuclide population: **inflow and daughtering**
- Losses to MCR radionuclide population: **outflow, recirculation filtration, and decay**
  - *Analysis framework can credit filtration and airflow changes, as applicable.*
- RRCAT currently used to perform numerical analysis and calculate dose at the following receptors:
  - EAB and LPZ (CEDE and EDE doses)
  - MCR occupancy (CEDE, EDE, and shine doses)



MCR Dose Assessment Approach

- MCR dose is evaluated for DBAs and for the Major Accident[(1)].
- Based on NSRST MCR classification, DBE source term used to evaluate 5 rem dose limit of PDC 19.
- DBE source term credits retention or removal of radionuclides prior to leaving the building originating the source rather than adding dependencies on MCR HVAC mechanisms.
- Off-site doses for DBAs always evaluated with DBA source term, enveloping dispersion factors, and crediting available SR SSCs only.
  - Worst 2-hour dose at the EAB, using DBA source term – 10CFR 50.34(a)(1)(ii)(D)(*1*)
  - 30-day TEDE dose at the LPZ, using DBA source term – 10CFR 50.34(a)(1)(ii)(D)(*2*)

(1) Major Accident definition proposed in 7/11/2023 engagement on "SARRDL, Major Accident, and Functional Containment."

Summary

MCR Habitability Summary

- Main Control Room
  - NSRST facility
  - Above ground in IBC-2021 and ASCE 7-16 facility
  - Two 50% HVAC units provide temperature and CO_2 control
  - HVAC units receive back-up NST diesel power
  - Radiological protection provided by Functional Containment, HVAC isolation and recirculation, and pressurized clear air
  - Toxic chemical protection (including sodium) provided by HVAC isolation/recirculation and:
    - HAZMAT suits or SCBAs if needed
    - Remote Shutdown Complex as contingency

Remote Shutdown Summary

- Remote Shutdown
  - Located underground in SR RPS/UPS facility
  - Remote Shutdown Complex located RPS Division Room
    - Bottled air manually aligned
    - 72-hour mission time
  - Reactor Trip breakers and other SR breakers located in proximity for prompt shutdown
  - Employed for fire in MCR, aircraft impact incidents, other beyond design basis events, and contingency for toxic chemicals and loss of MCR HVAC power

Questions?

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Acronym List

AOO – Anticipated Operational Occurrence
ASCE – American Society of Civil Engineers
BDBE – Beyond Design Basis Event
CEDE – Committed Effective Dose Equivalent
CFR – Code of Federal Regulations
CRBRP – Clinch River Breeder Reactor Project
DBA – Design Basis Accident
DBE – Design Basis Event
DBH – Design Basis Hazard
DBT – Design Basis Threat
DID – Defense-In-Depth
EAB – Exclusion Area Boundary
EBR – Experimental Breeder Reactor
EDE – Effective Dose Equivalent
EPZ – Emergency Planning Zone
F-C – Frequency-Consequence
FFTF – Fast Flux Test Reactor
GV – Guard Vessel
HAA – Head Access Area
HVAC – Heating, Ventilation, and Air Conditioning
HX – Heat Exchanger
IAC – Intermediate Air Cooling System
IEEE - Institute of Electrical and Electronics Engineers
ISP – Intermediate Sodium Pumps
LBE – Licensing Basis Event
LOOP – Loss of Offsite Power
LPZ – Low Population Zone
MCR – Main Control Room
NCB – Nuclear Island Control Building
NEI – Nuclear Energy Institute
NI – Nuclear Island
NRC – Nuclear Regulatory Commission
NSRST – Non-Safety-Related with Special Treatment
NST – Non-Safety-Related with No Special Treatment
PAM – Post-Accident Monitoring
PDC – Principal Design Criteria
PSP – Primary Sodium Pump
RAC – Reactor Air Cooling System
RES – Reactor Enclosure System
RG – Regulatory Guide
RIS – Reactor Instrumentation System
RPS – Reactor Protection System
RT – Reactor Trip
SBO – Station Blackout
SCBA – Self-Contained Breathing Apparatus
SCG – Sodium Cover Gas System
SFR – Sodium Fast Reactor
SR – Safety-Related
SRP – Standard Review Plan
SSC – Structures, systems, and components
TEDE – Total Effective Dose Equivalent
TMI – Three Mile Island
TREAT – Transient Reactor Test
UPS – Uninterruptable Power Supply
XIS – Nuclear Instrumentation System