April 14, 2023

TP-LIC-LET-0066
Project Number 99902100

U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001
ATTN: Document Control Desk

Subject: TerraPower MST and Rad Consequences Presentation Material

This letter provides the TerraPower, LLC presentation material for the upcoming "Mechanistic Source Term and Radiological Consequences" pre-application engagement meeting. The closed portion of the presentation material contains proprietary information and as such, it is requested that Enclosure 4 be withheld from public disclosure in accordance with 10 CFR 2.390, "Public inspections, exemptions, requests for withholding." Enclosure 4 also contains export-controlled information (ECI).

Enclosure 1 is an affidavit certifying the basis for the request to withhold proprietary content from public disclosure. Enclosure 3 contains the closed presentation material with appropriate redactions for proprietary and ECI content. Enclosure 4 transmits the entire presentation, including proprietary and ECI content. Enclosure 2 transmits content for the public portion of the meeting, which has no proprietary content.

This letter and enclosures make no new or revised regulatory commitments.

If you have any questions regarding this submittal, please contact Ryan Sprengel at rsprengel@terrapower.com or (425) 324-2888.

Sincerely,

Michael Montecalvo

Michael Montecalvo
Licensing Manager
TerraPower, LLC

Enclosures:

1. TerraPower, LLC Affidavit and Request for Withholding from Public Disclosure (10 CFR 2.390(a)(4))

2. "Mechanistic Source Term and Radiological Consequences (Public)" Presentation Material – Open Meeting – Non-Proprietary (Public)

3. "Mechanistic Source Term and Radiological Consequences (Redacted)" Presentation Material – Closed Meeting – Non-Proprietary (Public)

4. "Mechanistic Source Term and Radiological Consequences (Prop-ECI)" Presentation Material – Closed Meeting – Proprietary (Non-Public)

cc: Mallecia Sutton, NRC
Andrew Proffitt, NRC
William Jessup, NRC
Nathan Howard, DOE
Jeff Ciocco, DOE

ENCLOSURE 1

TerraPower, LLC Affidavit and Request for Withholding from Public Disclosure (10 CFR 2.390(a)(4))

Enclosure 1
TerraPower, LLC Affidavit and Request for Withholding from Public Disclosure
(10 CFR 2.390(a)(4))

I, George Wilson, hereby state:

1. I am the Vice President, Regulatory Affairs and I have been authorized by TerraPower, LLC (TerraPower) to review information sought to be withheld from public disclosure in connection with the development, testing, licensing, and deployment of the Natrium™ reactor and its associated fuel, structures, systems, and components, and to apply for its withholding from public disclosure on behalf of TerraPower.

2. The information sought to be withheld, in its entirety, is contained in Enclosure 4, which accompanies this Affidavit.

3. I am making this request for withholding, and executing this Affidavit as required by 10 CFR 2.390(b)(1).

4. I have personal knowledge of the criteria and procedures utilized by TerraPower in designating information as a trade secret, privileged, or as confidential commercial or financial information that would be protected from public disclosure under 10 CFR 2.390(a)(4).

5. The information contained in Enclosure 4 accompanying this Affidavit contains non-public details of the TerraPower regulatory and developmental strategies intended to support NRC staff review.

6. Pursuant to 10 CFR 2.390(b)(4), the following is furnished for consideration by the Commission in determining whether the information in Enclosure 4 should be withheld:

   a. The information has been held in confidence by TerraPower.

   b. The information is of a type customarily held in confidence by TerraPower and not customarily disclosed to the public. TerraPower has a rational basis for determining the types of information that it customarily holds in confidence and, in that connection, utilizes a system to determine when and whether to hold certain types of information in confidence. The application and substance of that system constitute TerraPower policy and provide the rational basis required.

   c. The information is being transmitted to the Commission in confidence and, under the provisions of 10 CFR 2.390, it is received in confidence by the Commission.

   d. This information is not available in public sources.

   e. TerraPower asserts that public disclosure of this non-public information is likely to cause substantial harm to the competitive position of TerraPower, because it would enhance the ability of competitors to provide similar products and services by reducing their expenditure of resources using similar project methods, equipment, testing approach, contractors, or licensing approaches.

I declare under penalty of perjury that the foregoing is true and correct.
Executed on: April 14, 2023

George Wilson

George Wilson
Vice President, Regulatory Affairs
TerraPower, LLC

ENCLOSURE 2

"Mechanistic Source Term and Radiological Consequences (Public)"
Presentation Material – Open Meeting

Non-Proprietary (Public)

TerraPower

NATRIUM

Mechanistic Source Term and Radiological Consequences Method Development Update

a TerraPower & GE-Hitachi technology

NAT-3417

SUBJECT TO DOE COOPERATIVE AGREEMENT NO. DE-NE0009054

Objectives

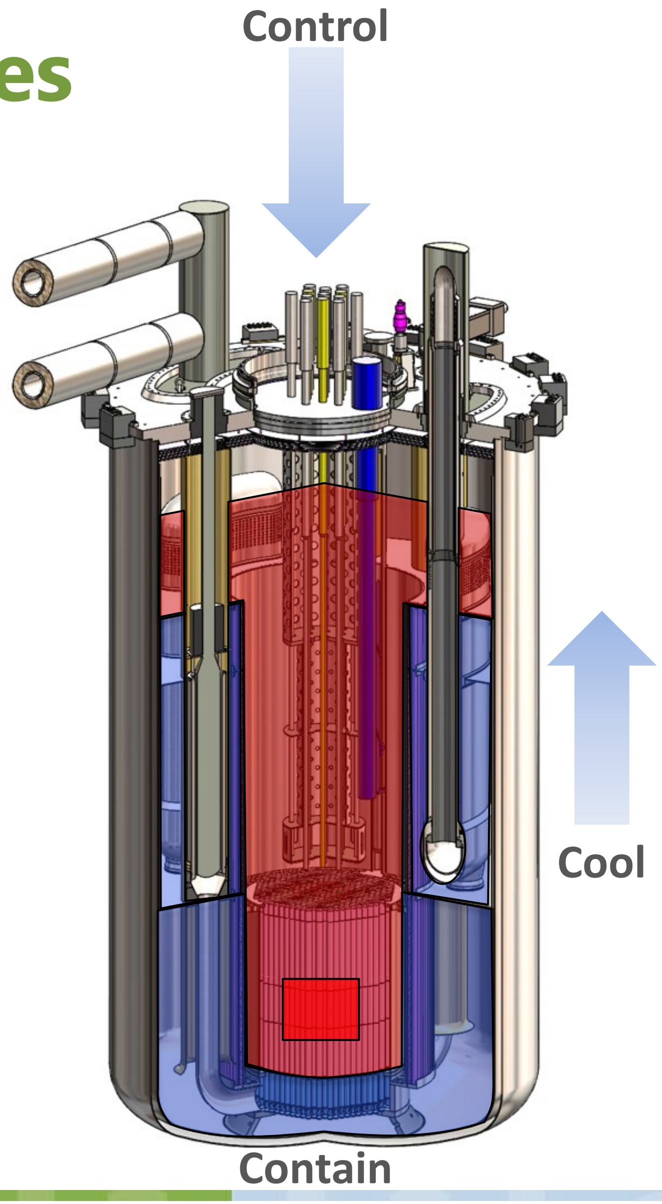
- Natrium™ Reactor Overview
- Natrium Source Term Methods Development Update
- Source Term Phenomena Identification and Ranking Tables
- Radionuclide Hazard Identification and Screening
- Source Term Analysis Update
- Licensing Basis Event (LBE) Radiological Consequence Methodology
- Design Basis Accident (DBA) Radiological Consequence Methodology

Advanced 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

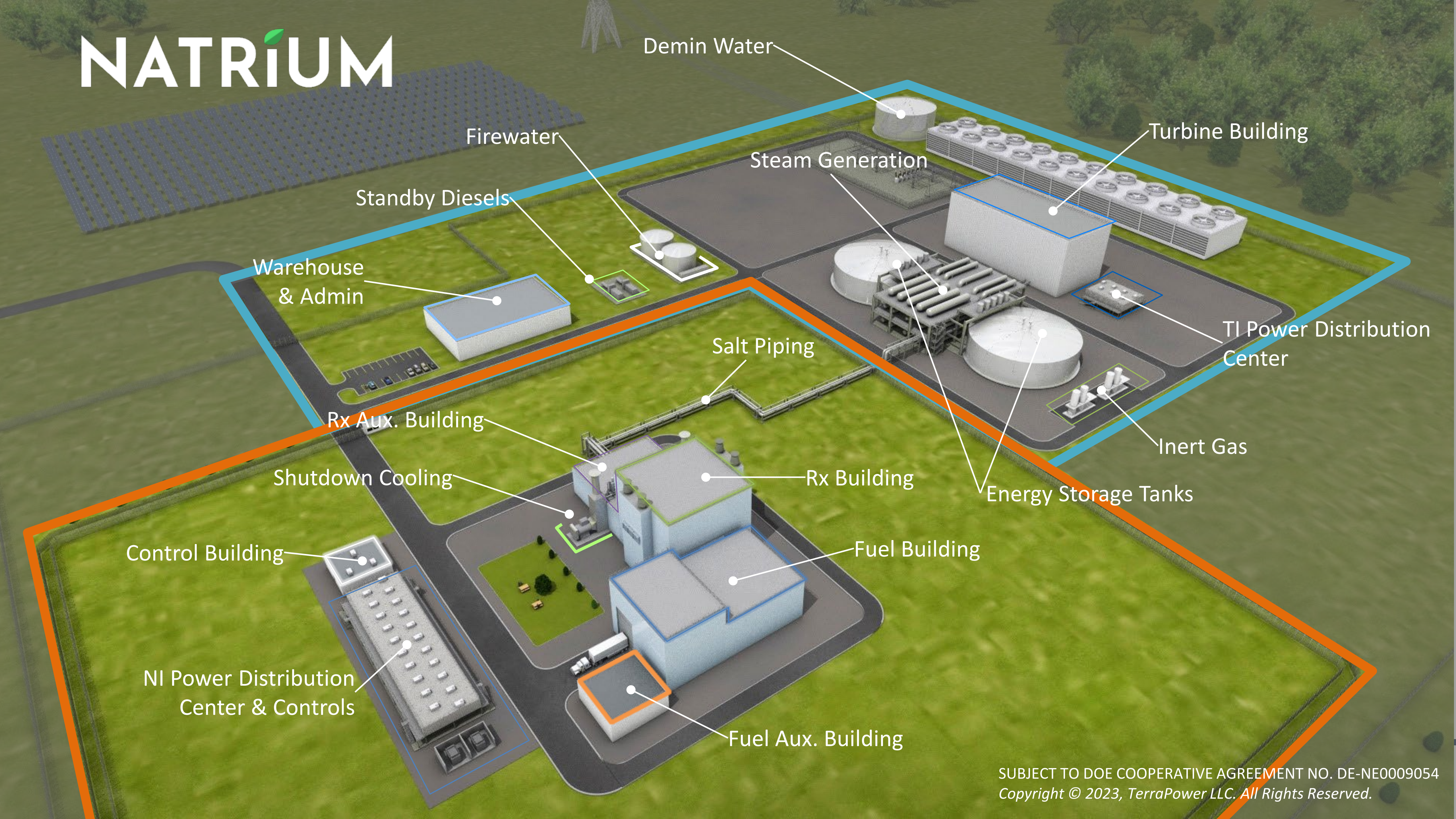
- Motor-driven control rod runback and scram follow
- Gravity-driven control rod scram
- Inherently stable with increased power or temperature

Cool

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

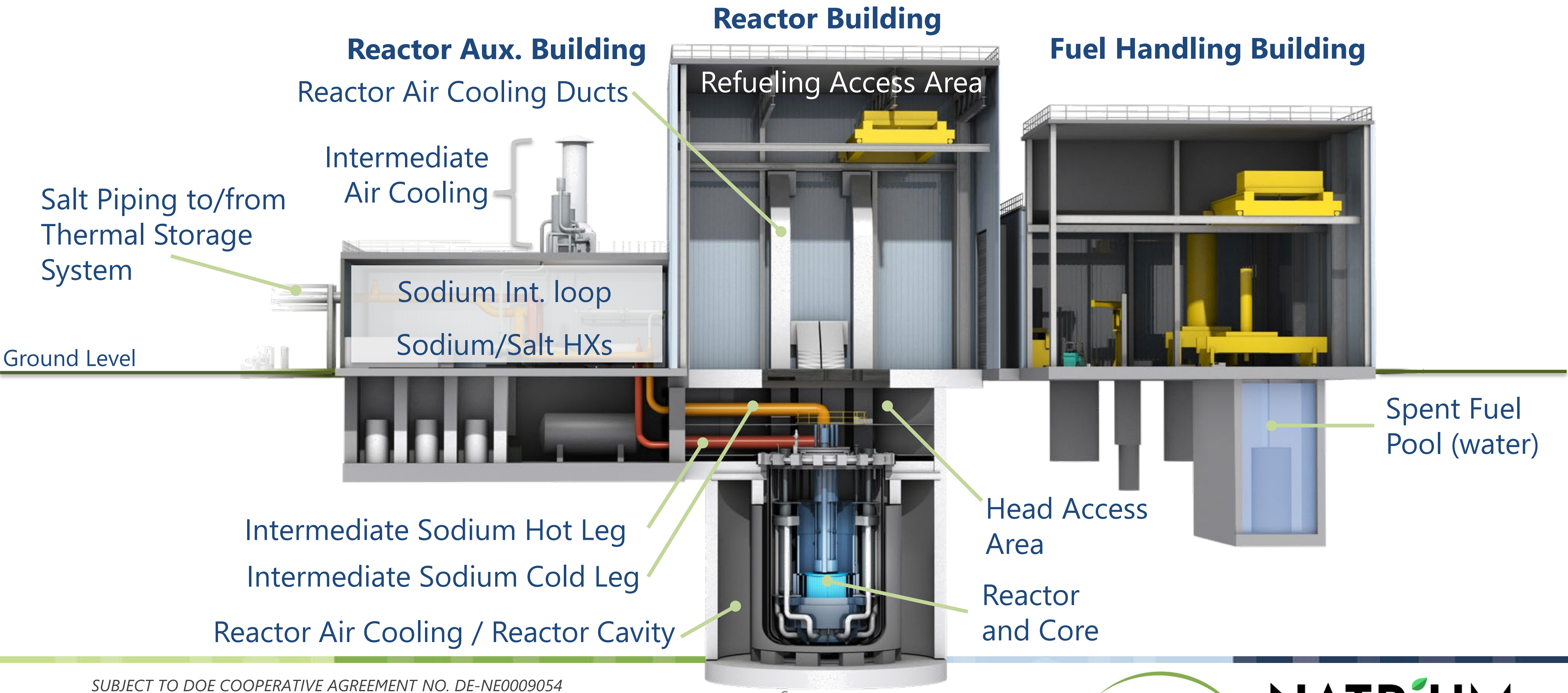
Contain

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



SUBJECT TO DOE COOPERATIVE AGREEMENT NO. DE-NE0009054

Plant Overview



SUBJECT TO DOE COOPERATIVE AGREEMENT NO. DE-NE0009054

TerraPower NATRIUM

SOURCE TERM METHODOLOGY DEVELOPMENT UPDATE

Methodology Development Update

- Plant Event Selection and Evaluation Process (January 2023)
  - Process for selecting and evaluating licensing basis events under RG 1.233/NEI 18-04
  - Methods for evaluation of events (e.g., Step 7 of NEI 18-04)

- Design Basis Accidents Methodology (March 2023)
  - Evaluation model development and assessment process for DBAs without radiological release

- SAS4A/SASSYS-1 (SAS) Methodology (April 2023)
  - SAS development and dedication
  - Benchmark and qualification

Source Term Methodology Development Update

- Phenomena Identification and Ranking Tables (PIRTs)
  - Completed for events with and without fuel failure
  - Details of the source term PIRT on the following slides
- Sodium Pool Scrubbing
  - Completion of the sodium pool scrubbing experiment at University of Wisconsin – Madison
  - On-going benchmark on sodium as well as water testing with Argonne National Laboratory
- Software Qualification
  - Pre-verification of evaluation models
  - Metal fuel model enhancements
  - Benchmarks on normal operations and transients

SOURCE TERM PIRT SUMMARY

Source Term PIRT

PIRT Process

1. Issue Definition
2. PIRT Objective
3. Hardware and Event Scenario
4. Evaluation Criteria
5. Current Knowledge Base
6. Phenomena Identification
7. Importance Ranking
8. Knowledge Level
9. Documentation

- An evaluation model (EM) is being developed to perform radiological source term analyses. The analyses will support a construction permit and operating license application.

- The PIRT identifies safety-relevant phenomena for radiological source term analyses, ranks importance based on pre-established Figures of Merit (FOMs), and ranks knowledge level to build a technical base for EM development and to identify potential gaps.

Source Term PIRT (Cont.)

PIRT Process

1. Issue Definition
2. PIRT Objective
3. Hardware and Event Scenario
4. Evaluation Criteria
5. Current Knowledge Base
6. Phenomena Identification
7. Importance Ranking
8. Knowledge Level
9. Documentation

- Hardware is the relevant systems and components including the reactor core, sodium processing system, and fuel handling systems.
- Several representative events were selected for the source term PIRT including fuel handling accidents and sodium processing system leaks.
- Evaluation focus was the impact of identified phenomena on FoMs (e.g., event-specific dose potential).

Source Term PIRT (Cont.)

PIRT Process

1. **Issue Definition**
2. **PIRT Objective**
3. **Hardware and Event Scenario**
4. **Evaluation Criteria**
5. **Current Knowledge Base**
6. **Phenomena Identification**
7. **Importance Ranking**
8. **Knowledge Level**
9. **Documentation**

- Three days of PIRT meetings.
- Expert panel consisted of six representatives from industry, national laboratories, and academia whose background work covered all areas being discussed.
- ~20 phenomena considered per event category (spent fuel interaction, aerosol behavior, and radionuclide transport).

Source Term PIRT (Cont.)

PIRT Process

1. Issue Definition
2. PIRT Objective
3. Hardware and Event Scenario
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8. Knowledge Level
9. Documentation

- The expert panel ranked identified phenomena based on importance with respect to the identified FoMs and knowledge level.

- If a phenomenon had a higher importance ranking than knowledge level, it was dispositioned for future work to close the gap.

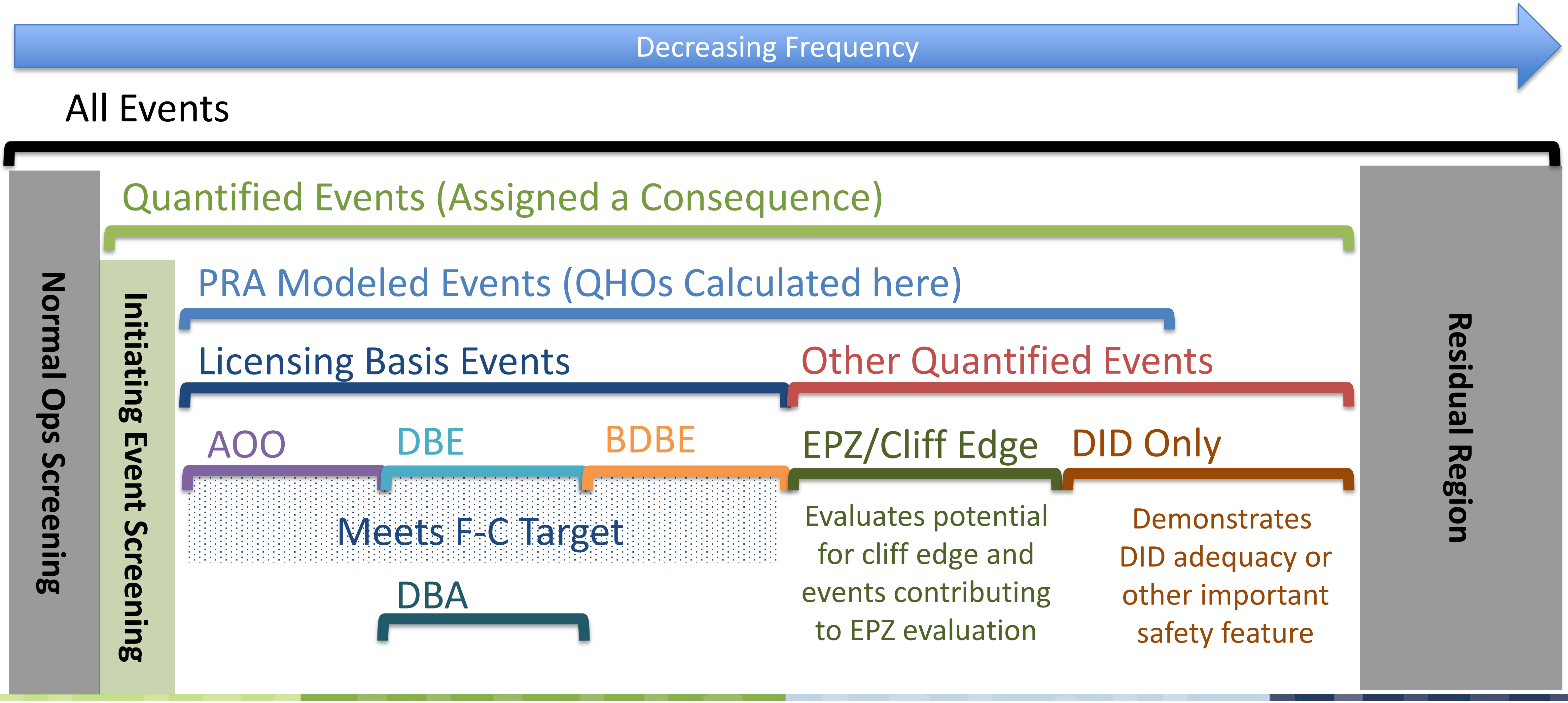
SOURCE TERM ANALYSIS

Key Source Term References

- **SRM-SECY-93-092** provides Commision endorsement of **"scenario specific"** source terms for advanced non-LWRs.
- Implemented through following NEI 18-04, endorsed by RG 1.233
- DOE Lab documents provide historical data relevant to SFR design and identification of source terms.

Document	Authoring Lab	Purpose / Description
SAND2021-11703	Sandia	Non-LWR Source Term Screening
ANL-ART-3	Argonne	Identify important SFR related radionuclides
ANL-ART-38	Argonne	Historical Metal Fuel experiments, and RN Release Fractions from Metal Fuel
ANL-ART-49	Argonne	Mechanistic Source Term Transport Trial Calculation

Event Type Line Diagram by Frequency



TerraPower NATRIUM

Identification of Radionuclide Sources and Screening

- **Identify Sources of Radionuclides (RN)**
  - **System by system review** to identify additional RN sources.
  - Most RN sources already included in PRA (full analysis treatment).
  - RN source identification comprehensive review to catch minor RN sources.
  - Identified sources (not in the PRA) get **screening evaluation**.
- **Screening of RN Sources**
  - Estimate **bounding system/component inventory**.
  - Perform **"parking lot" analysis**.
  - Evaluate bounding off-site dose against screening criteria.
  - Possible outcomes of screening:

Screening Result	Event Analysis Treatment
Dose screens from the F-C curve (e.g. < 2.5 mrem)	No LBE
Dose screens into the F-C curve but is not risk significant	Bounding LBE sufficient to cover RN system/source
Dose identified as possibly risk significant	Recommend inclusion in the PRA (full treatment)

Analysis of Source Terms

- **Normal Operation Source Terms**
  - Sodium activation
  - Tritium production and transport
  - Effluent calculation and release
  - Input to shielding analysis
  - Input to accident source term analysis

- **Accident Source Terms**
  - PRA categorizes all events (AOO/DBE/BDBE)
  - Source Term Events include:
    - LBEs determined to have release
    - Minor RN sources getting bounding LBE
    - DBAs w/ release (derived from DBEs)
    - Other Quantified Events

Event Analysis

- **Define source inventory**
  - In-vessel: core inventory
  - FHA: core component
  - Ex-vessel / Auxiliary System: system specific
- **Release Fractions and Timing**
  - Bounding assumptions, OR
  - Informed by supporting transient analyses
- **In-pin RN migration (core components)**
  - ANL-ART-38 and ANL-ART-49 data
- **Removal Mechanisms**
  - Pool Scrubbing – user specified DF or UW-M validation tests
  - Aerosol deposition – particle diameter and density dependent
  - Filtration – initially not credited for most events (conservative dose result)
- **Compartment Leakage Rates**
  - Iterating with design groups on various boundaries

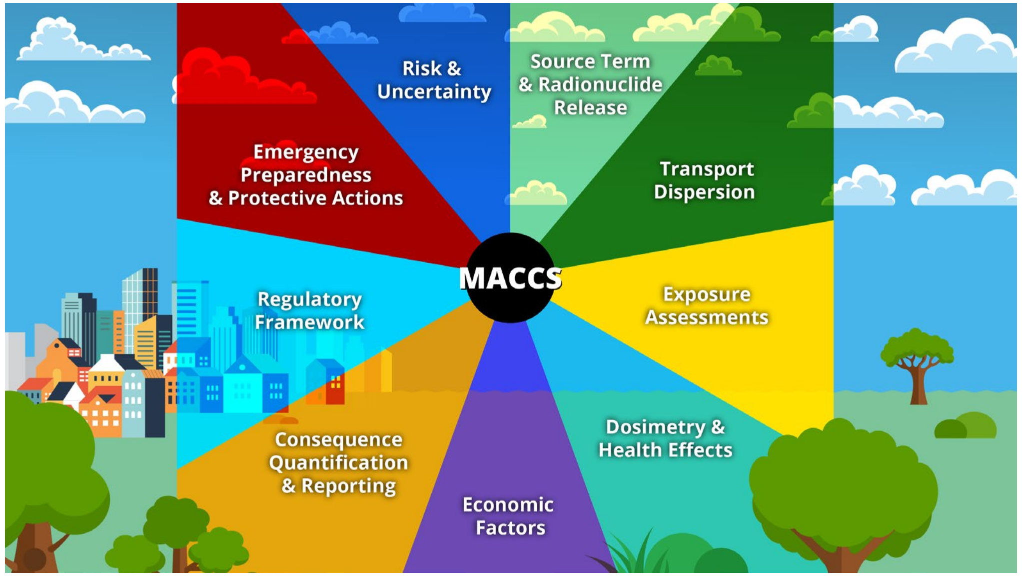
RADIOLOGICAL CONSEQUENCES

Objectives – Radiological Consequences

- Licensing Basis Event (LBE) Radiological Consequences Methodology Overview
  - Regulatory and LMP Requirements
  - Source Term Interface
  - Model Development

- Design Basis Accident (DBA) Radiological Consequences Methodology Overview
  - Regulatory and LMP Requirements
  - Source Term Interface
  - Analytical Models and Software

LICENSING BASIS EVENT (LBE) PROBABILISTIC SAFETY EVALUATIONS



LBE Regulatory and LMP Radiological Consequence Requirements

- Evaluation approach using a Technology-Inclusive, Risk-Informed, and Performance-Based (TI-RIPB) process per **Nuclear Energy Institute (NEI) 18-04 & Regulatory Guide (RG) 1.233**
- LMP & EPZ event sequences with radiological releases
- Event sequences evaluated to determine radiological consequences for the Frequency–Consequence (F-C) and Quantitative Health Objective (QHO) acceptance criteria
- The F-C curve anchor points are defined by 10 CFR 20, EPA PAG, 10 CFR 50.34 and, QHO criteria
- Additionally, **acute dose quantities are included to support EPZ analysis needs**

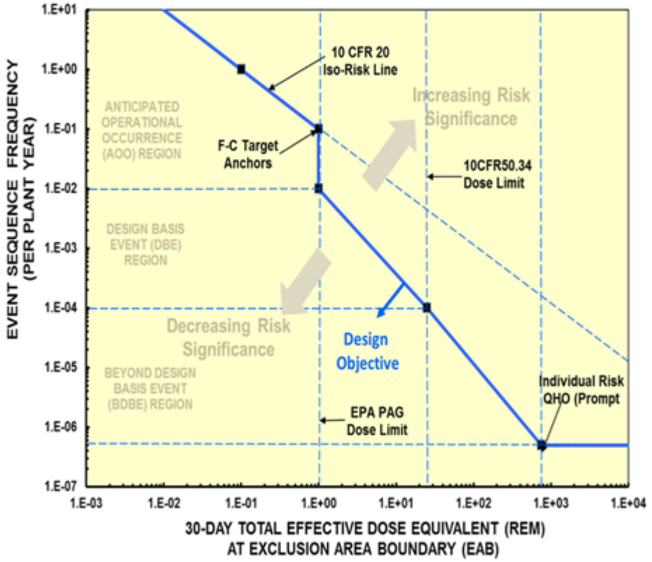


Figure 3-1. Frequency-Consequence Target

From NEI 18-04

LBE Radiological Consequence Analysis Source Term Interface

- **WinMACCS 4.1.0 code** selected for LBE Radiological Consequence Methodology
  - Version 4.0 SAND2021-8998 July 2021 w/4.1.0 Supplement (SAND2021-8667O)
- Mechanistic source term provides a release rate matrix
  - Large number of radionuclides exceeding code capabilities
  - Large number of time steps
- **A reduced set of important radionuclides are established to meet the code capabilities**

LBE Radiological Consequence Methodology – Plume Model

- Plumes defined based on mechanistic source term characteristics
- Plume segments calculated based on magnitude of the release over time to ensure the **plume model preserves source term characteristics**
- Plume of maximum risk (MAXRIS) defined based on the plume segment with the most significant release

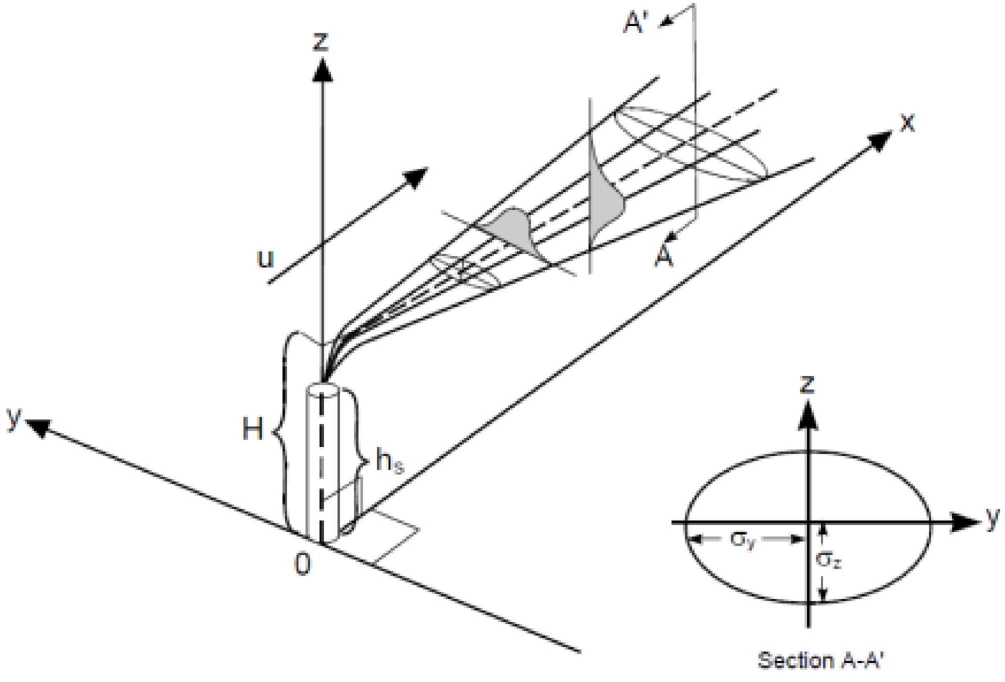
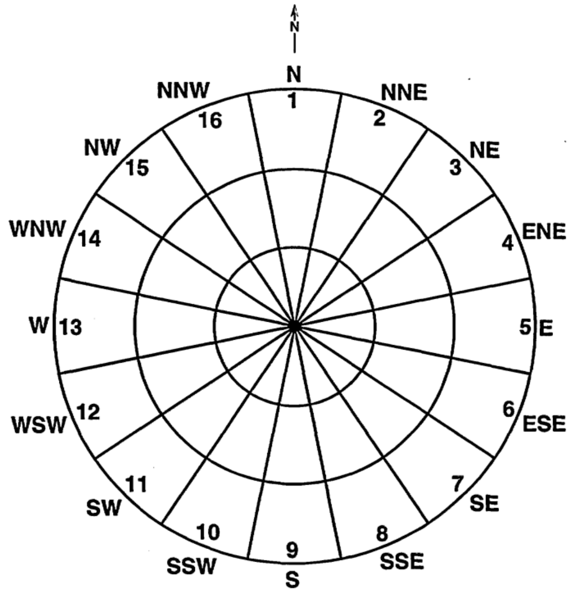


Figure A-1: Gaussian plume distribution and coordinate system
Source: Environmental Protection Agency

LBE Radiological Consequence Methodology - Offsite Model

- Spatial Grid
  - 16 compass sectors that are equivalent to a standard navigational compass rosette
  - 34 radial rings selected to meet calculational and QHO objectives
- Population Data – a uniform density is assumed for evaluation independent of site location (1,400 people/km²)
- Land Use Data, Economic Data, and Protective Actions
  - Evaluations focus on the first 30 days after a radiological event; therefore, MACCS input files for ingestion exposure and region-specific data for calculating long-term impacts and economic costs are not utilized
  - **No evacuation, relocation or sheltering were assumed**
  - **The public is assumed to continue normal activity**



From NUREG/CR-6631 Vol. 1

LBE Radiological Consequence Methodology - Offsite Model (Cont'd)

- Meteorological Data & Sampling
  - Non-uniform weather bin sampling using 1 year of meteorological data based on EPRI Technical Report 3002003129 "Utility Requirements Document" (URD)
- Dosimetry Information
  - Federal Guidance Reports (FGR) 11 & 12 dose conversion factors and FGR 13 cancer risk coefficients
  - Dose thresholds for risk based on NRC Linear No Threshold example problem
  - **Radiological consequences per MACCS Early module: 30 day TEDE at EAB, early fatality risk (EAB +1 mile) & cancer fatality (EAB + 10 mile)**

LBE Radiological Consequence Methodology – Dispersion

- Plume Dispersion Model
  - Ramsdell and Fosmire (RAF) model utilized out to 1200 meters (SAND2021-6924)
  - RAF plume meander used to account for both building wake effects and low wind speed plume meander based on increased nearfield capabilities
  - The Eimutis and Konicek parameterization of the Pasquill-Gifford diffusion curves is used for improved approximations to the vertical dispersion coefficient that match the Pasquill-Gifford curves at distances less than 500 meters from the source

LBE Radiological Consequence Methodology – Plume Depletion

- Radioactive decay is accounted for in the plume
- Wet and Dry Deposition
  - Developed based on SOARCA (NUREG/CR-7009 & NUREG/CR-7161)
  - Preliminary model based on NRC LNT example problem
- Wet and Dry Deposition modeling are pending sensitivity studies and validation against the Natrium source term

DESIGN BASIS ACCIDENT (DBA) DETERMINISTIC SAFETY EVALUATIONS

DBA Regulatory and LMP Radiological Consequence Requirements

- Per the LMP, DBAs are derived from the DBEs by prescriptively assuming that only Safety Related SSCs are available to mitigate postulated event sequence radiological consequences to within the **10 CFR 50.34 dose limits**

- PDC 19 requires adequate radiation protection be provided to permit **access and occupancy of the control room (CR)** under accident conditions without personnel receiving radiation exposures in excess of 5 rem TEDE for the duration of the accident

- Guidance in RG 1.183 related to radiological consequences is followed to the extent applicable to the Natrium design

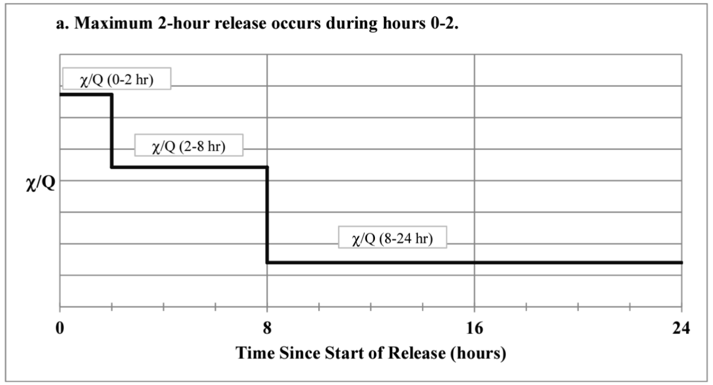
DBA Radiological Consequence Analysis Source Term Interface

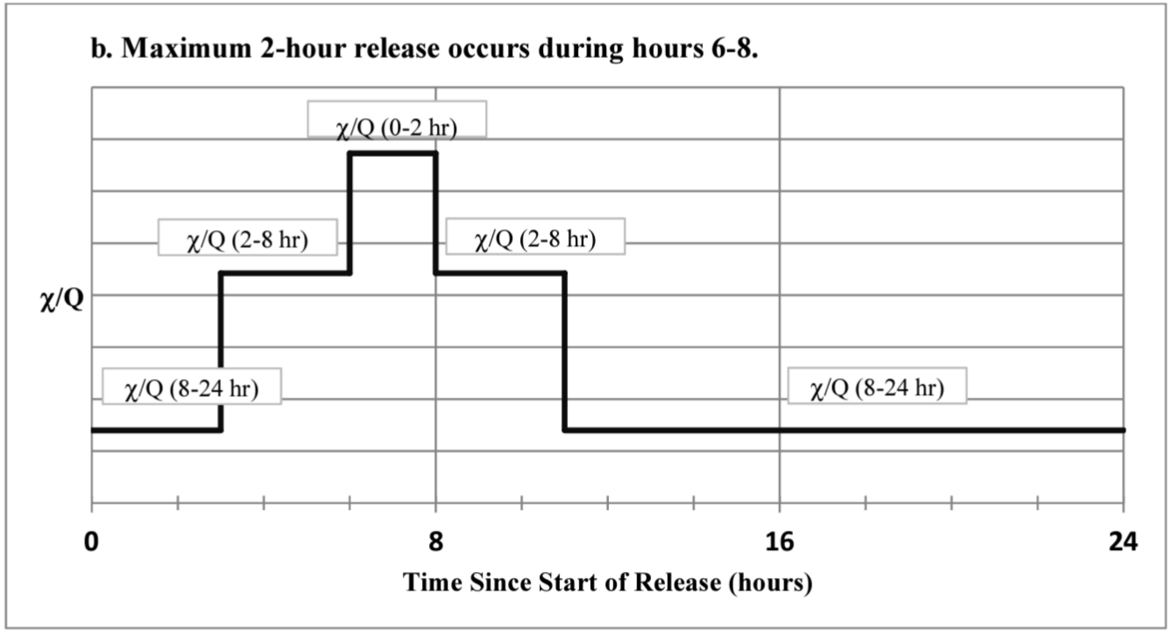
- There is no limitation on the number of radionuclides that can be modeled in DBA transport models

- **All radionuclides with data available are considered** in DBA scenarios
  - Required data includes release to environment from the source term and Dose Conversion Factors (DCFs) from FGRs 11 and 12

DBA Radiological Consequence Methodologies – Atmospheric Dispersion

- Dispersion of released radionuclides from release point to receptor location is captured using χ/Qs determined conservatively
- Timing of Low Population Zone (LPZ) and Control Room (CR) χ/Qs is **structured symmetrically** about the 2-hour period of **most limiting release**
  - 2-hour period aligned with the highest 2-hour dose delivered to a receptor at the Exclusion Area Boundary (EAB)
- Alignment of limiting χ/Qs with limiting releases is considered to ensure non-LWR DBA scenarios are analyzed conservatively
- Approach is consistent with guidance in RG 1.194 Sec. 2 for the CR, DG-1389 Fig. 2 shown on the right



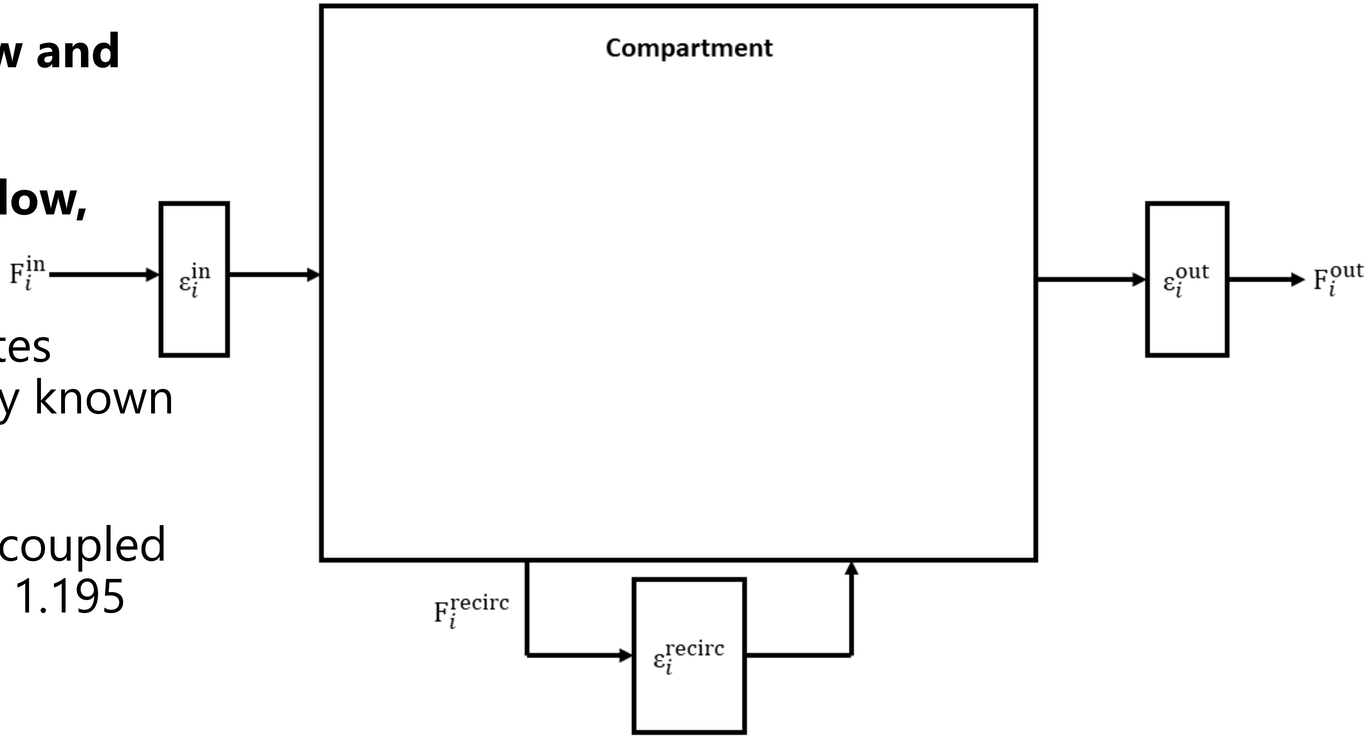


DBA Radiological Consequence Methodologies – Offsite Receptors

- 10 CFR 50.34(a): The dose to a receptor on the EAB must be no greater than **25 rem TEDE over any 2-hour period**
  - Determined by applying the 0-2 hour χ/Q and a breathing rate of 3.5e-4 m^3/sec for the duration of the accident
- 10 CFR 50.34(a): The dose to a receptor on the boundary of the LPZ must be no greater than **25 rem TEDE over the duration of the accident**
  - Determined by assuming the breathing rates provided in RG 1.183, Section 4.1.3

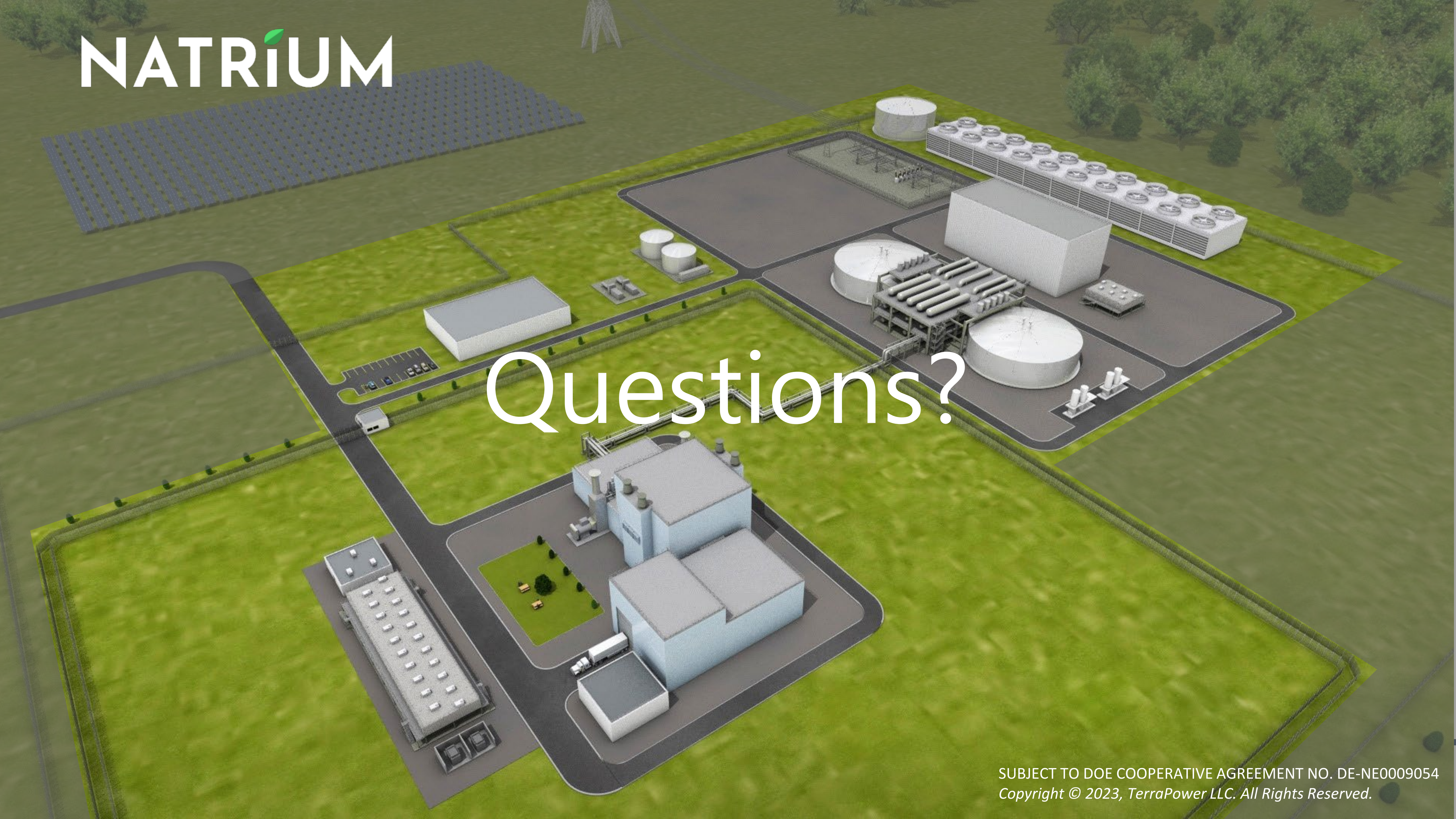
DBA Radiological Consequence Methodologies – Control Room

- The CR is modeled as a single compartment only exchanging air with the environment
- Gains to radionuclide population in CR: **inflow and daughtering**
- Losses to radionuclide population in CR: **outflow, recirculation filtration, and decay**
  - Filtration equipment credited and flow rates assumed in DBA analyses are not currently known due to state of design
- Radionuclide populations in CR expressed as coupled system of ODEs that is solved numerically, RG 1.195 Eq. 4 with daughtering terms



DBA Code Implementation - RRCAT

- Released Radionuclide Consequence Analysis Tool (RRCAT) was developed by the GE-Hitachi radiological consequence analysis team for this work
  - Input with release to environment, χ/Qs, CR flows, dose conversion factors (DCFs), and other model information
  - Calculates activity concentration in the environment and CR and activity accumulation on filtration equipment
  - Calculates resultant dose using conversion factors
  - Functionality is similar to and benchmarked against RADTRAD 3.10
- Used to calculate dose to a receptor at the EAB, at the LPZ, or accessing the CR considering **CEDE and EDE** dose
- Used to calculate dose to an operator occupying the CR considering **CEDE, EDE, and shine dose**



NATRIUM

Questions?

SUBJECT TO DOE COOPERATIVE AGREEMENT NO. DE-NE0009054

Acronym List

AC – Alternating Current
AOO – Anticipated Operational Occurrence
ARCAP – Advanced Reactor Content of Application Project
ARDC – Advanced Reactor Design Criteria
ARDP – Advanced Reactor Demonstration Program
BDBE – Beyond Design Basis Event
CEDE – Committed Effective Dose Equivalent
CFR – Code of Federal Regulations
CR – Control Room
DBA – Design Basis Accident
DBE – Design Basis Event
DCF – Dose Conversion Factor
DF – Decontamination Factor
DID – Defense-in-Depth
DOE – Department of Energy
EAB – Exclusion Area Boundary
EBR – Experimental Breeder Reactor
EDE – Effective Dose Equivalent
EM – Evaluation Model
EPRI – Electric Power Research Institute
EPZ - Emergency Planning Zone
F-C – Frequency-Consequence
FFTF – Fast Flux Test Facility
FGR – Federal Guidance Report
FHA – Fuel Handling Accident
FoM – Figure of Merit
GDC – General Design Criteria
GE-H – General Electric – Hitachi
HX – Heat Exchanger
LBE – Licensing Basis Event
LMP – Licensing Modernization Project
LNT – Linear No-Threshold
LPZ – Low Population Zone
LWR – Light Water Reactor

Acronym List (Cont.)

MST – Mechanistic Source Term
NI – Nuclear Island
NRC – U.S. Nuclear Regulatory Commission
ODE – Ordinary Differential Equation
PAG – Protective Action Guide
PDC – Principal Design Criteria
PIRT – Phenomena Identification and Ranking Tables
PRA – Probabilistic Risk Assessment
PSAR – Preliminary Safety Analysis Report
QHO - Quantitative Health Objective
RAF - Ramsdell and Fosmire
RG – Regulatory Guide
RIPB – Risk-Informed, Performance-Based
RN – Radionuclide
RRCAT - Released Radionuclide Consequence Analysis Tool
SFR – Sodium Fast Reactor
SOARCA – State Of the Art Reactor Consequence Analyses
SSC – Structures, Systems, and Components
TEDE – Total Effective Dose Equivalent
TI – Turbine Island
TI-RIPB – Technology-Inclusive, Risk-Informed, and Performance-Based
TICAP – Technology Inclusive Content of Application Project
TREAT – Transient Reactor Test
URD – Utility Requirement Document
UW-M – University of Wisconsin - Madison

SUBJECT TO DOE COOPERATIVE AGREEMENT NO. DE-NE0009054

TerraPower NATRIUM

ENCLOSURE 3

"Mechanistic Source Term and Radiological Consequences (Redacted)"
Presentation Material – Closed Meeting

Non-Proprietary (Public)

NATRIUM

Mechanistic Source Term and Radiological Consequences Method Development Update

a TerraPower & GE-Hitachi technology

NAT-3418

SUBJECT TO DOE COOPERATIVE AGREEMENT NO. DE-NE0009054

Portions of this presentation are considered export controlled information (ECI). ECI can be disclosed to Foreign Nationals only in accordance with the requirements of 15 CFR 730 and 10 CFR 810, as applicable.

Portions of this presentation are considered proprietary and TerraPower, LLC requests it be withheld from public disclosure under the provisions of 10 CFR 2.390(a)(4).

Nonproprietary versions of this presentation indicate the redaction of such information using [[ ]](a)(4),[[ ]]ECI, or [[ ]](a)(4), ECI.

Table of Contents

PIRT DEVELOPMENT

Source Term PIRT

PIRT Process

1. Issue Definition
2. PIRT Objective
3. Hardware and Event Scenario
4. Evaluation Criteria
5. Current Knowledge Base
6. Phenomena Identification
7. Importance Ranking
8. Knowledge Level
9. Documentation

- An evaluation model (EM) is being developed to perform radiological source term analyses. The analyses will support a construction permit and operating license application.
- The PIRT identifies safety-relevant phenomena for radiological source term analyses, ranks importance based on pre-established Figures of Merit (FOMs), and ranks knowledge level to build a technical base for EM development and to identify potential gaps.

Source Term PIRT (Cont.)

PIRT Process

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- Hardware is Natrium™ demonstration plant systems and components.
- The following three representative events were selected for the source term PIRT:
  - fuel handling accidents (FHAs)*
  - leak or rupture of the sodium processing system (SPS)*

[[

]](a)(4)

**The rest of this section will focus on the ex-vessel events*

Source Term PIRT (Cont.)

PIRT Process

1. Issue Definition
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Source Term PIRT (Cont.)

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PIRT Process

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Source Term PIRT (Cont.)

PIRT Process

[[

1. Issue Definition
2. PIRT Objective
3. Hardware and Event Scenario
4. Evaluation Criteria
5. Current Knowledge Base
6. Phenomena Identification (1 of 3)
7. Importance Ranking
8. Knowledge Level
9. Documentation

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Source Term PIRT (Cont.)

PIRT Process

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1. Issue Definition
2. PIRT Objective
3. Hardware and Event Scenario
4. Evaluation Criteria
5. Current Knowledge Base
6. Phenomena Identification (2 of 3)
7. Importance Ranking
8. Knowledge Level
9. Documentation

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Source Term PIRT (Cont.)

PIRT Process

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1. Issue Definition
2. PIRT Objective
3. Hardware and Event Scenario
4. Evaluation Criteria
5. Current Knowledge Base
6. Phenomena Identification (3 of 3)
7. Importance Ranking
8. Knowledge Level
9. Documentation

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Source Term PIRT (Cont.)

PIRT Process

[[

1. Issue Definition
2. PIRT Objective
3. Hardware and Event Scenario
4. Evaluation Criteria
5. Current Knowledge Base
6. Phenomena Identification
7. Importance Ranking
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Source Term PIRT (Cont.)

PIRT Process

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1. Issue Definition
2. PIRT Objective
3. Hardware and Event Scenario
4. Evaluation Criteria
5. Current Knowledge Base
6. Phenomena Identification
7. Importance Ranking
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SOURCE TERM ANALYSIS UPDATE

Source Term Analysis Topics

- RN Source Screening Example Results
  - Review Screening Criteria
  - Radiological Waste Systems Screening
- In-vessel vs. Ex-vessel Analysis
  - Analysis tools
  - Key inputs
  - Reference data
- Example LBE Analysis

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Simplified Radionuclide Transport (SRT) Code

- DOE code developed and maintained by **Argonne National Lab (ANL)**
- **Closes SFR analysis gap** (2016) where no single transport tool existed to perform SFR MST analysis
  - Mechanistic Source Term (MST) Trial Calcs: ANL-ART-3 and ANL-ART-49
- Performs time-dependent radionuclide transport/retention analysis
- SFR specific models:
  - Sodium **pool and bubble transport** model
  - Time/temperature/burnup dependent **metal fuel radionuclide migration** and **release fractions** for pin plenum and matrix
- Code Versions
  - Current Release: version 2.0.2
  - Next Full Release: version 2.1 (expected Spring 2023)

Simplified Radionuclide Transport (SRT) Code

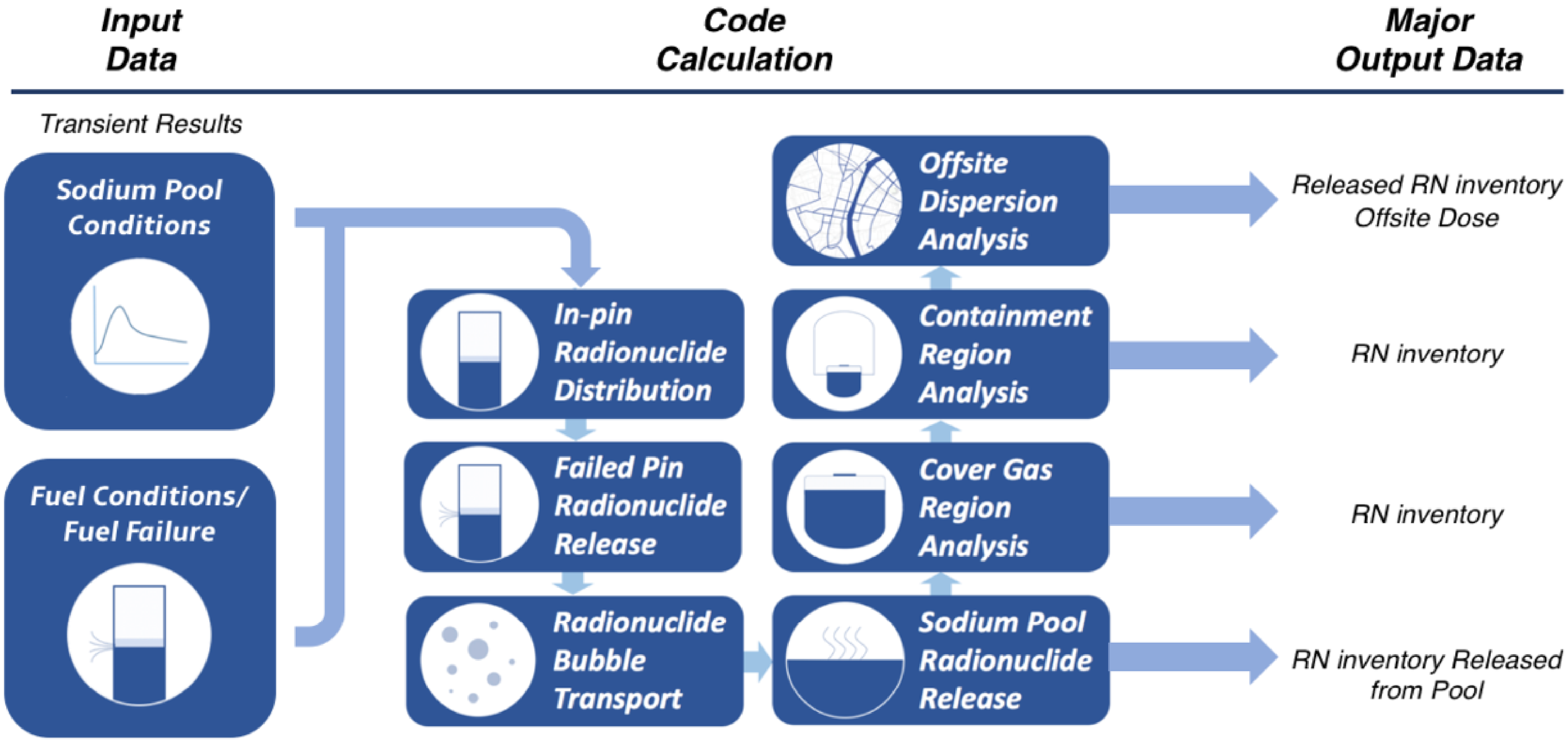

Figure 1 from ANL-SRT-4

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RADIOLOGICAL CONSEQUENCES UPDATE

Objectives

- LBE Radiological Consequence Analysis Source Term Interface
- LBE MACCS Plume Model
- LBE Sensitivity and Uncertainty Analyses
- DBA Accident-Specific Dose Limits

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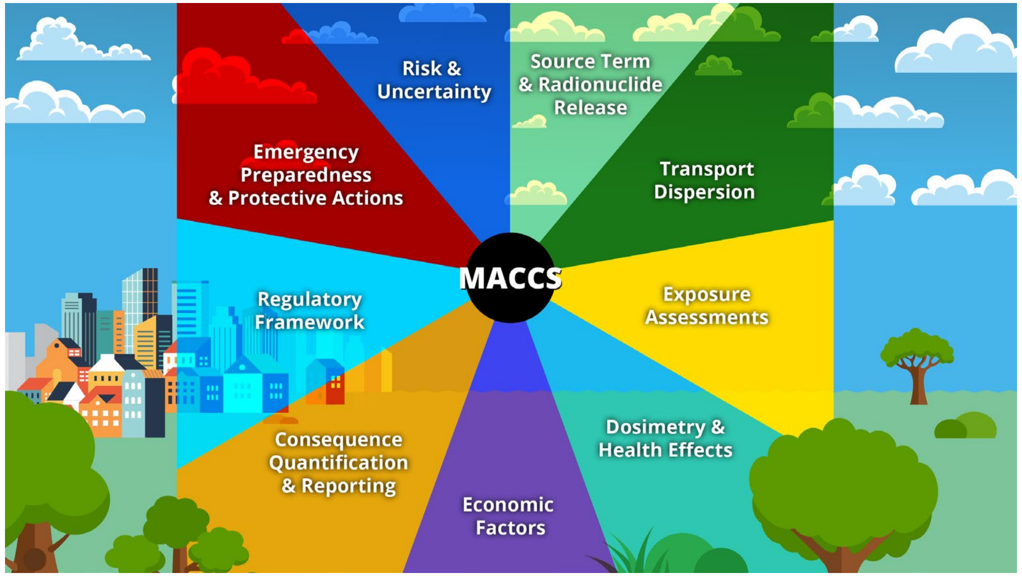
Licensing Basis Event (LBE) Probabilistic Safety Evaluations



LBE Radiological Consequence Analysis Source Term Interface

- **WinMACCS 4.1.0 code** selected for LBE Radiological Consequence Methodology
- Mechanistic source term provides a release rate matrix
  - Large number of radionuclides exceeding code capabilities
  - Large number of time steps
- **A reduced set of important radionuclides are established to meet the code capabilities**

LBE Radiological Consequence Analysis Source Term Interface

- Radionuclide releases to environment from the source term may include hundreds of radionuclides
- MACCS transport models are limited to 150 radionuclides
- A ranking evaluation was performed

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LBE Radiological Consequence Methodology – Plume Model

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LBE Radiological Consequence Methodology – Plume Model (Cont'd)

- Plume Segment Example
  - Event scenario involving relatively long duration release

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LBE Radiological Consequence Methodology – Plume Model (Cont'd)

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LBE Radiological Consequence Methodology - Sensitivities and Uncertainties

- Sensitivity and Uncertainty Methodology in development
- Sensitivities have been performed to inform and justify the preliminary MACCS Model:

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LBE Radiological Consequence Methodology - Sensitivities and Uncertainties

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Design Basis Accident Deterministic Safety Evaluations

DBA Regulatory Requirements – Accident-Specific Limits

- The LMP interpretation of DBAs is that they are:
  - Subject to 10 CFR 50.34 and PDC 19 dose limits as previously presented
  - **Not subject to accident-specific dose limits**

- 25% or 10% of 10 CFR 50.34 limits are specified for certain accident scenarios in NUREG-0800 Sec. 15.0.3 Table 1 and RG 1.183 Table 6
  - The Natrium (non-LWR) design **is not subject to NUREG-0800 and RG 1.183**; they are only followed as guides to the extent applicable

- The radiological consequences of all LBEs are assessed against the F-C Target
  - F-C Target includes consideration for event frequency
  - DBA frequency cannot be well estimated due to prescriptive analysis assumptions (only Safety Related SSCs available)

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Sample LBE Calculation: Source Term and Radiological Consequences

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Questions?

Acronym List

ALARA – As Low As Reasonably Achievable
ANL – Argonne National Laboratory
ANS – American Nuclear Society
AOO – Anticipated Occupational Occurrence
ASME – American Society of Mechanical Engineers
CFR – Code of Federal Regulations
CPA – Construction Permit Application
CR – Control Room
DBA – Design Basis Accident
DBE – Design Basis Event
DCF – Dose Conversion Factor
DOE – Department of Energy
DPA – Displacement per Atom
DU – Depleted Uranium
EAB – Exclusion Area Boundary
EBR – Experimental Breeder Reactor
EM – Evaluation Model
EPA – Environmental Protection Agency
EVHM – Ex-Vessel Handling Machine
FA – Fuel Assembly
FFTF – Fast Flux Test Facility
FGR – Federal Guidance Report
FHA – Fuel Handling Accident
FOM – Figure of Merit
GNF-A – Global Nuclear Fuels – Americas LLC
GWe – Gigawatt Electric
GWe-yr – Gigawatt Electric Year
HEPA – High-Efficiency Particulate Air
HM – Heavy Metal
HX – Heat Exchanger
IAC – Intermediate Air Cooling
INL – Idaho National Laboratory

Acronym List (Cont.)

Int. – Intermediate
IVTM – In-Vessel Transfer Machine
LBE – Licensing Basis Event
LMP – Licensing Modernization Project
LNT – Linear No Threshold
LPZ – Low Population Zone
LWR – Light Water Reactor
MST – Mechanical Source Term
NRC – U.S. Nuclear Regulatory Commission
P-F – Power to Flow
PAG – Protective Action Guideline
PIC – Pool Immersion Cell
PIRT – Phenomena Identification and Ranking Table
PRA – Probabilistic Risk Assessment
RG – Regulatory Guide
RN – Radionuclide
RRCAT – Released Radionuclide Consequence Analysis Tool

RV – Reactor Vessel
RVH – Reactor Vessel Head
RWG – Gaseous Radiological Waste
RWL – Liquid Radiological Waste
RWS – Solid Radiological Waste
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SFP – Spent Fuel Pool
SFR – Sodium Fast Reactor
SNF – Spent Nuclear Fuel
SOARCA – State Of the Art Reactor Consequence Analyses
SPS – Sodium Processing System
SRT – Simplified Radionuclide Transport
SSC – Structures, Systems, and Components
TEDE – Total Effective Dose Equivalent
TREAT – Transient Reactor Test
TWR – Traveling Wave Reactor
ULOF+ – Unprotected Loss of Flow with degraded pump coastdown

SUBJECT TO DOE COOPERATIVE AGREEMENT NO. DE-NE0009054