U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

Advanced Reactor Stakeholder Meeting on Form and Content of an Application for Non-Light Water Reactors and Discussion of Draft Report on Molten Salt-Fueled Reactor Fuel Qualification Methodology

April 22, 2020

Telephone Bridgeline: (888) 989-3418

Passcode: 9074476#

Advanced Reactor Program

Agenda

Time	*Topic*	*Speaker*
9:00 - 9:10 am	Opening Remarks	NRC
9:10 - 9:30am	Overview of Technology Inclusive Content of Application Project (TICAP)	Southern
9:30 -10:00 am	Status of TICAP Comments on the NRC's Proposed Outline	Southern
10:00 -10:20 am	Updates on Proposed Outline for Content of Application Including Technical Specifications	NRC
10:20 - 10:40 am	Discussion of Licensing Modernization Project Based Safety Case	Southern
10:40 - 10:50 am	Break	All
10:50 - 11:20 am	Status and Highlights of Draft Report on Molten Salt Fueled Reactor Fuel Qualification Methodology	NRC/ORNL
11:20 - 11:45 am	Industry Presentation on Desired Outcomes on Molten Salt Fuel Reactor Content of Application	Southern
11:45 - 12:00 pm	General Discussion on Next Steps for Advanced Reactor Content of Application Project	All

Overview

Technology Inclusive Content of Application Project (TICAP)

Steve Nesbit
LMNT Consulting

Advanced Reactor Stakeholder Meeting
April 22, 2020

Southern Company

Outline of Presentation

- TICAP Goal and Approach
- Licensing Modernization Project (LMP) Safety Case
- Molten Salt Reactor (MSR) Fuel Qualification
- Key TICAP Products

TICAP Goal

Develop an endorsable document that outlines the content of an application in a manner that is technology inclusive, risk-informed, performance-based and its scope is limited by LMP methodology and can be submitted to NRC for endorsement

- Output will likely be a process for developing content of application as opposed to a specific set of required information
- Current content of application requirements are LWR-based
  - Advanced reactor safety cases may not require description of certain design features and/or programs (e.g., emergency electrical power, human factors)
- Products and schedules are subject to change as the project evolves

TICAP

Department of Energy cost-shared, Southern Company-led project

Guidance for developing content for key elements of the NRC license application Safety Analysis Report (SAR)

- Applicable to all non-LWR designs
- Leverages advanced reactor features such as passive safety
- Builds on foundation provided by LMP

Development team consisting of owner-operators, advanced reactor developers and consultants

Ultimate product is an NRC-endorsable NEI guidance document

Licensing Modernization Project (LMP)

Department of Energy cost-shared, Southern Company-led project

Risk-Informed, Performance-Based Approach to

- Selection of Licensing Basis Events
- Classification of Structures, Systems, and Components (SSCs)
- Defense-in-Depth adequacy determination

NEI 18-04 Rev. 1, Risk Informed Performance Based Guidance for Non-Light Water Reactor Licensing Basis Development (Aug 2019)

NRC Draft Guide 1353, Guidance for a Technology-Inclusive, Risk-Informed, and Performance-Based Approach to Non-Light-Water Reactors (April 2019)

LMP Safety Case Use of Fundamental Safety Functions

- Fundamental Safety Functions (FSFs) – apply to all designs
- PRA Safety Functions
  - Design-specific
  - Derive from FSFs
- Required Safety Functions
  - Determine safety-related SSCs
- Non-safety Related SSCs with Special Treatment
  - Risk-significant functions
  - Defense-in-depth adequacy

Molten Salt Reactor Fuel Qualification

- Fuel is an important SSC for all advanced reactor designs
  - Relates to all three FSFs
- Oak Ridge National Laboratory will be discussing its draft report on MSR Fuel Qualification
- TerraPower will be addressing MSR fuel qualification and the relationship with LMP and TICAP

Key TICAP Products

Fundamental Safety Functions (FSFs) Definition

Regulation Mapping to FSFs

Formulation of Technology Inclusive Content of Application

Differences Between Licensing Paths

NEI Guidance Document Annotated Outline

LMP-Related Safety Case

Tabletop Exercises

NEI Guidance Document

Questions?

TICAP Comments on NRC SAR Outline

Technology Inclusive Content of Application Project (TICAP)

Steve Nesbit
LMNT Consulting

Advanced Reactor Working Group Meeting
September 22, 2019

Southern Company

Outline of Presentation

- Nuclear Regulatory Commission (NRC) Draft Outline for an Advanced Reactor License Application
- TICAP Comments

NRC Draft Outline

- Developed by NRC with support of Idaho National Laboratory
  - Provided for industry review November 2019
  - Draft outline of Final Safety Analysis Report (FSAR)
  - Licensing documents outside the scope of an FSAR
- Presented at the December 12, 2019 NRC Advanced Reactor Stakeholder Meeting
  - "Draft outline addresses full scope of a combined license but it could be adapted for other applications"
  - "Starting point is Licensing Modernization Project (NEI 18-04)"
  - "Expectation is that FSAR portion of an application would be more detailed for safety-related structures, systems, and components (SSCs) and less detailed for other SSCs"

NRC Draft Outline (cont.)

- 14 chapters in SAR
- 21 additional portions of applications identified
- Next steps (per NRC in December 2019)
  - Major focus of discussions in upcoming stakeholder meetings and/or dedicated meetings; coordination with industry-led TI-CAP
  - NRC will be interacting with Canadian Nuclear Safety Commission
  - Staff will revise draft outline as appropriate and provide updated draft outline in March 2020 time frame
  - Planned development of a regulatory guide

TICAP Comments

- Caveats
  - These comments are provided on behalf of the TICAP team and do not purport to represent a consensus on the part of the nuclear industry
    - » Developed by small team with emphasis on developers and utilities
  - TICAP has not developed a preferred organization for an advanced reactor SAR
    - » Recommended changes do not always accompany comments
  - Comments should be considered in multiple contexts
    - » Current 10 CFR Part 50 and Part 52 world
    - » Future 10 CFR Part 53 world
  - Outlines do not enable a complete understanding of what is desired and/or the expected level of detail
    - » "The devil is in the details, but so is the salvation" – Admiral Hyman Rickover

TICAP Comments (General)

- Number of attractive attributes of the NRC outline
  - Departs from standard format and content guidelines geared toward conventional large light water reactors
  - Begins with general plant information
  - Safety case first
  - Addresses key elements of LMP
    - » Selection of licensing basis events (LBEs)
    - » Safety classification of structures, systems and components (SSCs) and associated risk-informed special treatments
    - » Defense-in-depth (DID) adequacy

TICAP Comments (Specific)

- Chapter 1 – General Information
  - Should be structured so as to be understandable and useful not only to the NRC but to the broader stakeholder community
  - Potential for overlap with other chapters (e.g., Chapter 2 Site Information)
  - Need to understand desire for separate sections on analytical codes and methods verification and validation, referenced materials, drawings, and conformance with regulatory guides
- Chapters 3 through 5 - LBE Analysis, SSCs, and Design Basis Accidents (DBAs)
  - Key elements of LMP
  - Optimal organization of this information in a SAR is work in progress for TICAP

TICAP Comments (Specific)

- Chapter 3 – LBE Analysis
  - Need to better understand the scope and intent of Section 3.2 Mechanistic Source Term
  - Need to better understand what is expected in Section 3.3 Frequency – Consequence Criteria
- Chapter 4 – SSCs
  - “By category” approach may not be optimal
  - Need to understand use of “Primary Safety Function” term in lieu of “Fundamental Safety Function”

TICAP Comments (Specific)

- Chapter 7 – DID
  - Not clear separating DID discussion from LBEs and SSCs is optimal
  - Need to understand intent of 7.2.5 Technical Specifications to Bound Uncertainties
  - Need to understand reason for inclusion of emergency plan information
- Chapter 11 – Physical Security
  - Need to understand reason for inclusion of security information in the SAR rather than a separate, non-public document (i.e., the Physical Security Plan)
- Chapter 12 – Overview of PRA
  - Key element of LMP methodology
  - Perhaps should be earlier in the document

TICAP Comments (Specific)

- Chapter 13 Administrative Controls
  - Important to limit this section to programs with a nexus to public health and safety
  - Intent of 13.6 Change Control Process not clear – different from 10 CFR 50.59?
- Separate Licensing Documents
  - Generally beyond TICAP scope – did not perform detailed review
  - Need to flesh out intent and rationale, particularly for those without established precedent
  - Expectations with respect to PRA deserve discussion
    - » Document submittal vs. regulatory audit

Summary

- Important to establish an improved framework for advanced reactor applications
- TICAP team appreciates NRC's efforts toward that end and looks forward to additional dialog

Questions?

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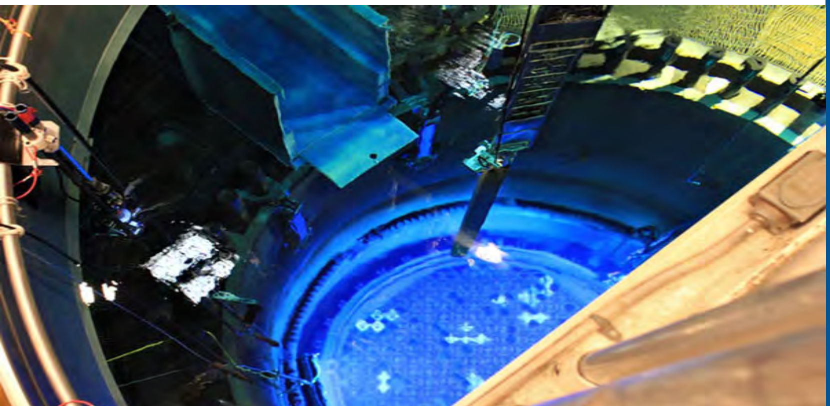
Advanced Reactor Content of Application Project (ARCAP)

NRR/DANU – Advanced Reactor Policy Branch
US Nuclear Regulatory Commission
with Support from
Idaho National Laboratory

April 22, 2020



Advanced Reactor Content of Application Project (ARCAP)

- Staff's draft outline was discussed on Dec. 12 and is found in ADAMS at Accession No. ML19325C089
- Draft outline addresses Sections 1 through 14
  - Final safety analysis report (FSAR) portion of application
- Staff's draft outline has now been "annotated" to suggest additional background and clarification regarding FSAR section content
  - Annotated outline is found in ADAMS at Accession No. ML20107J565
  - Continues to include a summary listing of other (non-FSAR) portions of an application for consideration

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Informing Content of Applications

Outline (FSAR) with major licensing modernization project (LMP) areas highlighted

Introduction

1. General Information*
2. Site Information
3. Licensing Basis Event (LBE) Analysis*
4. Integrated Plant Analysis*
5. Description and Classification of SSCs*
6. Design Basis Accidents Analysis (10 CFR 50.34)*
7. Defense in Depth (DID)*
8. Control of Routine Plant Radioactive Effluents and Solid Waste
9. Control of Occupational Dose
10. Human Factors Analysis*
11. Physical Security
12. Overview of PRA*
13. Administrative Control Programs* *(special treatment)*
14. Initial Startup Programs* *(special treatment)*

Additional Portions of Application

- Technical Specifications
- Technical Requirements Manual
- Quality Assurance Plan (design)
- Fire Protection Program (design)
- PRA
- Fuel qualification report
- Exemptions
- Quality Assurance Plan (construction and operations)
- Emergency Plan
- Physical Security Plan
- SNM (special nuclear materials) physical protection program
- SNM material control and accounting plan
- Cyber Security Plan
- New fuel shipping plan
- Fire Protection Program (operational)
- Radiation Protection Program
- Offsite Dose Calculation Manual
- Inservice inspection/Inservice testing (ISI/IST) Program
- Environmental Report
- Site Redress Plan
- Exemptions, Departures, and Variances

Format and Content

Question on International Alignment (e.g., CNSC, IAEA)

- Industry interest in pursuing alignment ?

I. Introduction
II. General Plant Description
III. Management of Safety
IV. Site Evaluation
V. General Design Aspects
VI. Description of Plant Systems
VII. Safety Analyses
VIII. Commissioning
IX. Operational Aspects
X. Operational Limits and Conditions
XI. Radiation Protection
XII. Emergency Preparedness
XIII. Environmental Aspects
XIV. Radioactive Waste Management
XV. Decommissioning and End of Life Aspects

Format and Content

Questions for ARCAP Content

- Is the general direction incorporated into the ARCAP outline consistent with the Technology Inclusive Content of Application Project (TICAP) direction?
- Should ARCAP scope include construction permit guidance
  - What should ARCAP include in this area?
  - Does TICAP include a construction permit process?
- Should ARCAP include guidance for microreactors?
- Does the ARCAP draft annotated outline have an appropriate level of detail?
- Are there other topics that should be included in the draft?
- Are there items in the draft that are inconsistent with LMP?

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Format and Content

Questions for ARCAP Content

- Should the outline be updated to allow LMP concepts to be used in other sections of the outline that are not typically associated with the process? (e.g., risk inform quality assurance program, radioactive waste management).
  - Should performance-based criteria for inspection of Part 20 requirements be used vice a licensing review?
- Routine release and ALARA requirements (contained in 10CFR20, App. B, and 10CFR50, App. I, respectively) are based on LWR technology. How should ARCAP address these performance-based requirements for non-LWR technology?
- What non-LMP topics traditionally found in the FSAR should be relocated from the FSAR to a separate (non-50.59 controlled) application document?

Format and Content

Questions on Alignment for Technical Specifications (10 CFR 50.36)

- Construct of Technical Specifications
  - Safety Limits, Limiting Safety System Settings
  - Limiting Conditions of Operation (LCOs), Surveillance Requirements
    - Associated 4 Criteria
    - LCOs represent the “lowest functional capability or performance levels of equipment required for safe operation”
  - Design Features, Administrative Controls
  - Use exemptions or guidance?
  - Replace or define “Significant Safety Function” language in 50.36?

Format and Content

Questions on Alignment for Technical Specifications (10 CFR 50.36)

- Scope of Technical Specifications (TS)
  - Should LCOs address only requirements for “safety-related structures, systems and components (SSCs)” or also address “non-safety-related with special treatment?”
  - Relationship between TS, safety classification, and requirements associated with “adequate protection” and “safety enhancements”?
  - Which events should LCOs address? [All, or a subset of licensing basis events (e.g., Design Basis Accidents)]?
  - Role of administrative controls in maintaining configurations and reliability of SSCs consistent with licensing basis events and frequency-consequence targets

LMP-Based Safety Case

Technology Inclusive Content of Application Project (TICAP)

Jason Redd
Southern Nuclear Development

NRC Public Meeting
April 22, 2020

Southern Company

Outline of Presentation

- TICAP Definition of Safety Case
- LMP-Based Safety Case
- Fundamental Safety Functions-centered LMP-Based Safety Case Development
- Scope of LMP-Based Safety Case
- LMP-Based Safety Case Inputs and Outputs
- Next Steps

TICAP Definition of Safety Case

- IAEA-TECDOC-1814 defines the “safety case” of a nuclear facility as follows:

  “a collection of scientific, technical, administrative and managerial arguments and evidence in support of the safety of a [nuclear] facility covering the suitability of the site and the design, construction, and operation of the facility, the assessment of radiation risks and assurance of the adequacy and quality of all the safety related work associated with the [nuclear] facility.”

- TICAP intends to adopt the above definition of “safety case” for the purposes of this specific project.

- The LMP-Based Safety Case is a key element of demonstrating that a non-LWR design provides reasonable assurance of adequate protection of the health and safety of the public.

LMP-Based Safety Case

- The LMP-Based Safety Case is an affirmative safety case.

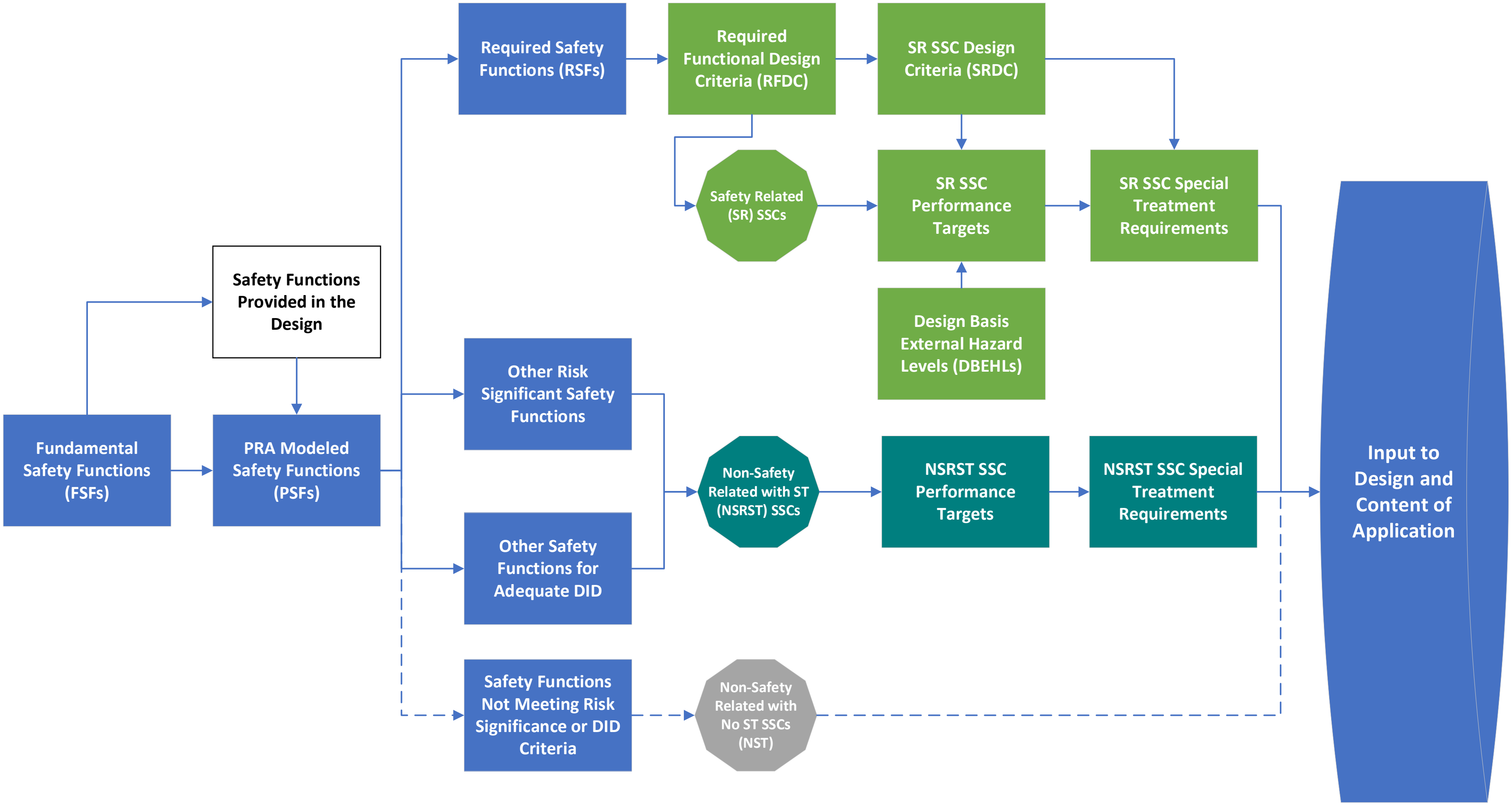
- The LMP-Based Safety Case is based on satisfying the three technology-inclusive fundamental safety functions (FSFs) which underpin all regulations within the scope of the LMP-Based Safety Case:
  - Retaining Radioactive Materials
  - Controlling Reactivity
  - Removing Heat from the Reactor and Waste Stores

FSF-centered LMP-Based Safety Case Development

- Satisfaction of the FSF is the common element that stretches throughout the LMP RIPB process and LMP-Based Safety Case.

- As shown in the following figure, the nuclear facility features created by the designer are incorporated into the design-specific PRA model, then design-specific safety functions flow logically to the design-specific SSC and their attributes which are then incorporated in the content of an application.

FSF-centered LMP-Based Safety Case Development



Scope of LMP-Based Safety Case

- As stated in NEI 18-04, Section 1.3, the LMP RIPB guidance "describes acceptable processes for selection of LBEs; safety classification of SSCs and associated risk-informed special treatments; and determination of DID adequacy"

- The LMP-Based Safety Case does not address all regulations which are applicable to a nuclear facility application, i.e. financial qualifications of the applicant, material control and accountability, etc.

LMP-Based Safety Case Inputs and Outputs

- Successful implementation of the LMP RIPB process and construction of the LMP-Based Safety Case requires a multitude of inputs to produce actionable outputs to inform the design and technical content of applications.

  – Input such as reliability data, design information, analytical programs, and tools such as a probabilistic risk assessment;

  – Analyses and evaluations to generate and select the Licensing Basis Events (LBEs), classify Structures, Systems, and Components (SSCs), and determine defense-in-depth (DID) adequacy;

  – Output such as tables of LBEs by frequency groups; Tables of SSC with classifications and special treatments as required, and the baseline evaluation of DID for the facility.

Next Steps

- Drafting of Rev. A of report in progress.
- Report to be provided to the NRC for review and comment in Late Summer 2020.
- Report to be completed Fall 2020.

Break

Meeting/Webinar will begin shortly

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Fuel Salt Qualification Method Overview

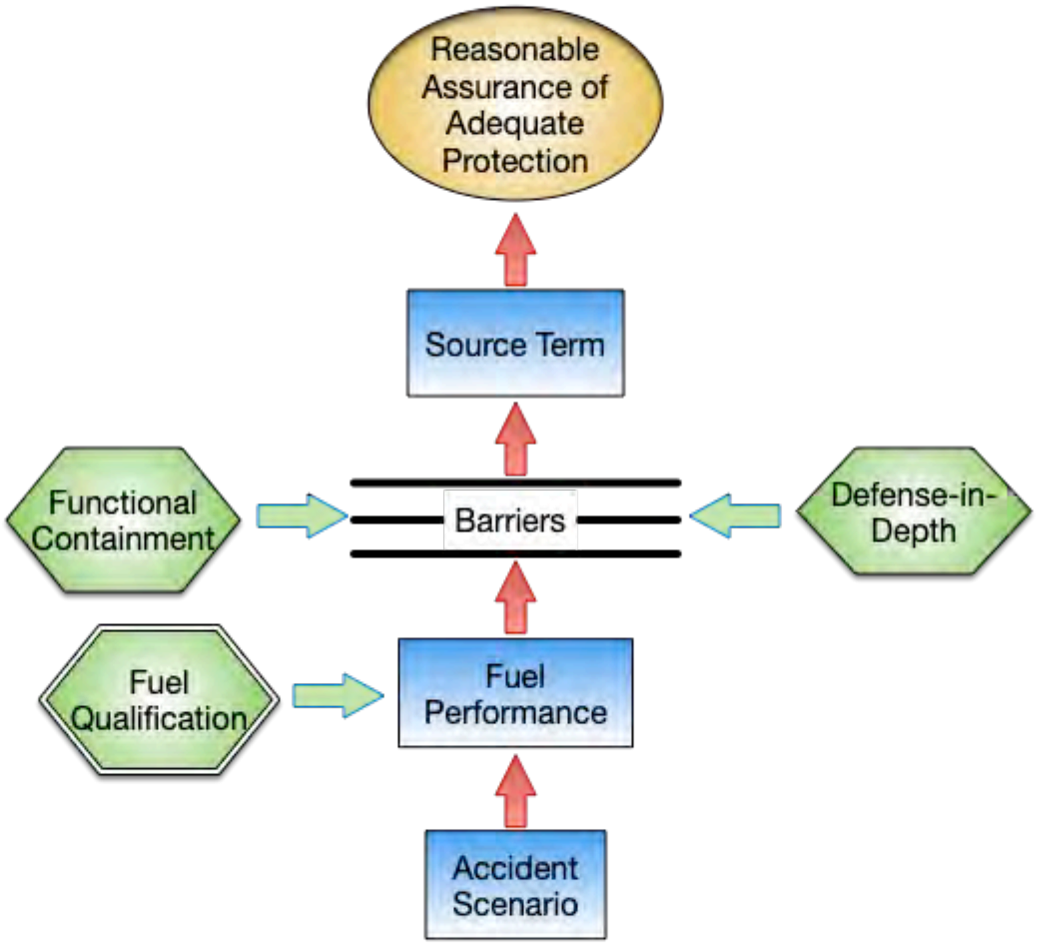
Advanced Reactor Stakeholder Meeting (On-line)

David Holcomb, George Flanagan, and Mike Poore

April 22, 2020

ORNL is managed by UT-Battelle, LLC for the US Department of Energy

Fuel Qualification is an Element in Achieving Sufficient Understanding of Fuel Behavior



Fuel qualification is a process which provides high confidence that physical and chemical behavior of fuel is sufficiently understood so that it can be adequately modeled for both normal and accident conditions, reflecting the role of the fuel design in the overall safety of the facility. Uncertainties are defined so that calculated fission product releases include the appropriate margins to ensure conservative calculation of radiological dose consequences. - ML17220A315

No Qualification Method Appropriate for Liquid Salt Fuel Currently Exists

- Existing fuel qualification methodology is based upon the characteristics and safety functions of solid fuels
- Role of liquid fuel salt in plant safety is significantly different from solid fuels
  - Physical and chemical behaviors are significantly different
- Stakeholders have indicated that significant confusion and delay would result from attempting to apply a solid fuel-based methodology to liquid salt fuel

Safety Functions	
Solid Fuel	**Liquid Salt Fuel**
Retain radionuclides	Retain some radionuclides
Maintain coolable geometry	Provide decay heat removal
Provide net negative prompt reactivity feedback	Provide net negative reactivity feedback

Key Issue is “What Constitutes Fuel Salt?”

- Fuel salt does not come in discrete elements (rods or assemblies) and moves independently of its container during normal operations
  - Cladding and fuel assembly structures are qualified as part of solid fuel
- Fuel salt includes all of the material containing fissionable elements or radionuclides that remain in hydraulic communication, but not the surrounding systems, structures, or components
  - Salt vapors and aerosols remain part of the fuel salt system until they become trapped adequately
  - Container corrosion products become part of the fuel salt
  - Fresh and used fuel salt in on-site storage are within scope

Qualification is Based Upon Understanding the Chemical and Physical Properties of Representative Fuel Samples

- Liquid state significantly changes the physical behavior of fuel
  - Liquids do not accumulate internal stresses
    - No history dependent properties
  - Flow homogenizes fluid properties
    - No position dependent properties
    - No size dependent properties
- Chemical and physical properties are set by elemental composition and temperature
  - Independent of isotopic content

Small non-radioactive liquid fuel salt samples provide representative physical and chemical properties

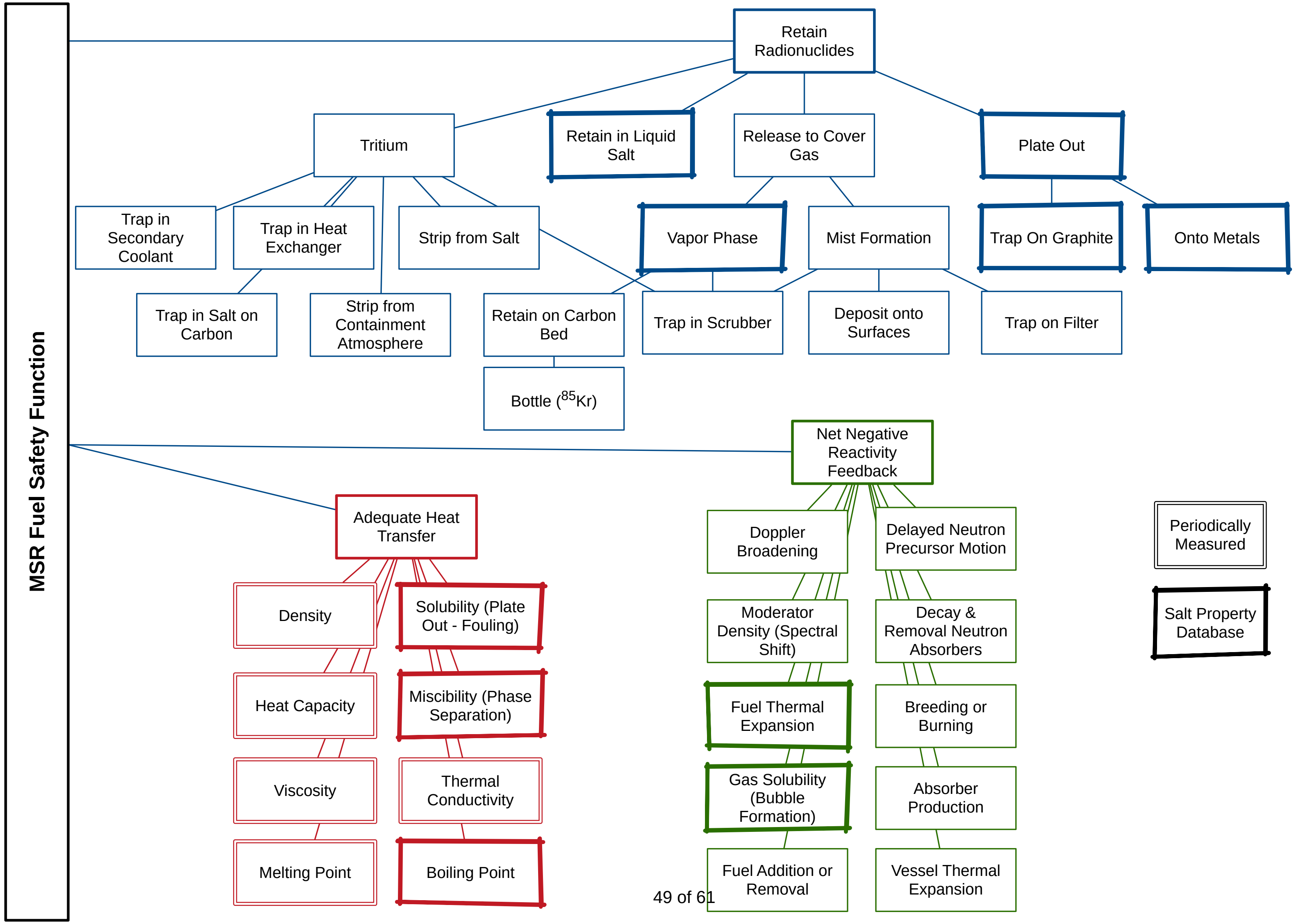
Liquid Fuel Salt Qualification Establishes Acceptable Salt Composition Range That Maintains Safety Functions

- Liquid fuel salt is a Newtonian fluid
  - Heat transfer and fluid flow behave in well known manners
  - Continuous variance in physical properties with composition
- Reasonable assurance of adequate protection derives from a combination of measured salt composition and knowledge of consequent chemical and physical properties
- A liquid fuel salt property database would capture the relationship between fuel salt composition and properties

Liquid Salt Property Database Relates Composition to Physical and Chemical Properties

- Database development underway under DOE-MSR campaign
  - Salt property measurement program in progress
    - Not currently including minor constituent transuranic elements (Am, Cu)
  - Requires appropriate quality assurance for both new and existing data
- Database initially sparsely populated
  - Safety evaluations / accident models performed with bounding values to establish acceptable performance range
- Additional data added to database over time
- Goal is to eventually only require salt composition measurement at operating plants and look up properties from database

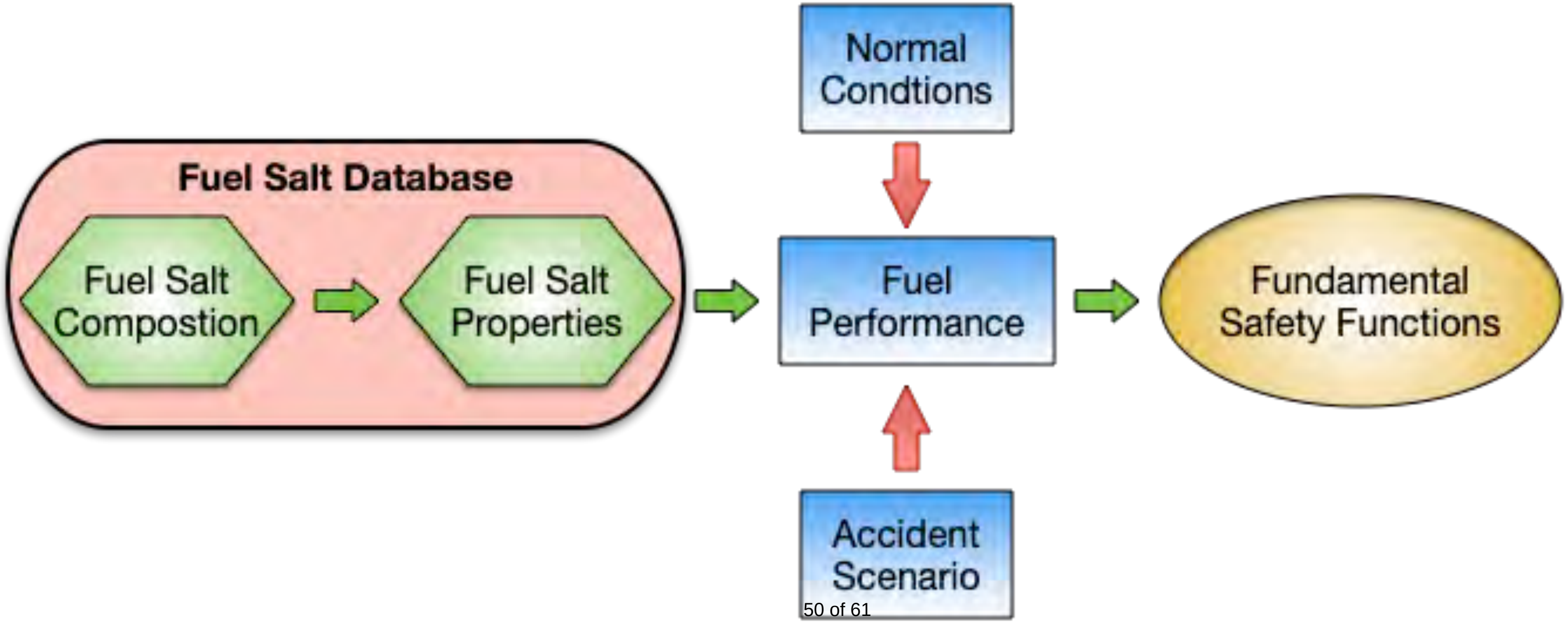
Database and Measured Properties Combine To Support Safety Function Demonstration



OAK RIDGE National Laboratory

Fuel Salt Properties Support Modeling Reactor Performance Under Normal and Accident Conditions

- Heat transfer in Newtonian fluids is determined primarily by density, viscosity, and heat capacity
  - Thermal conductivity and radiative heat transfer parameters can become important in specialized situations



Periodic Fuel Salt Property Assessment Will Be an Element of Reactor Operations

- Analogous to material surveillance coupons
  - Compare measurement to prediction
- Frequency of property measurement depends on potential rate of change and how close salt composition is to allowable limits
  - Chromium composition was measured weekly at MSRE
  - Uranium content was inferred from reactivity impact
  - MSRE did not accumulate sufficient fission products to require reassessing most properties: density, viscosity, etc.

Fuel Salt Properties are a Significant Part of Establishing a Mechanistic Source Term

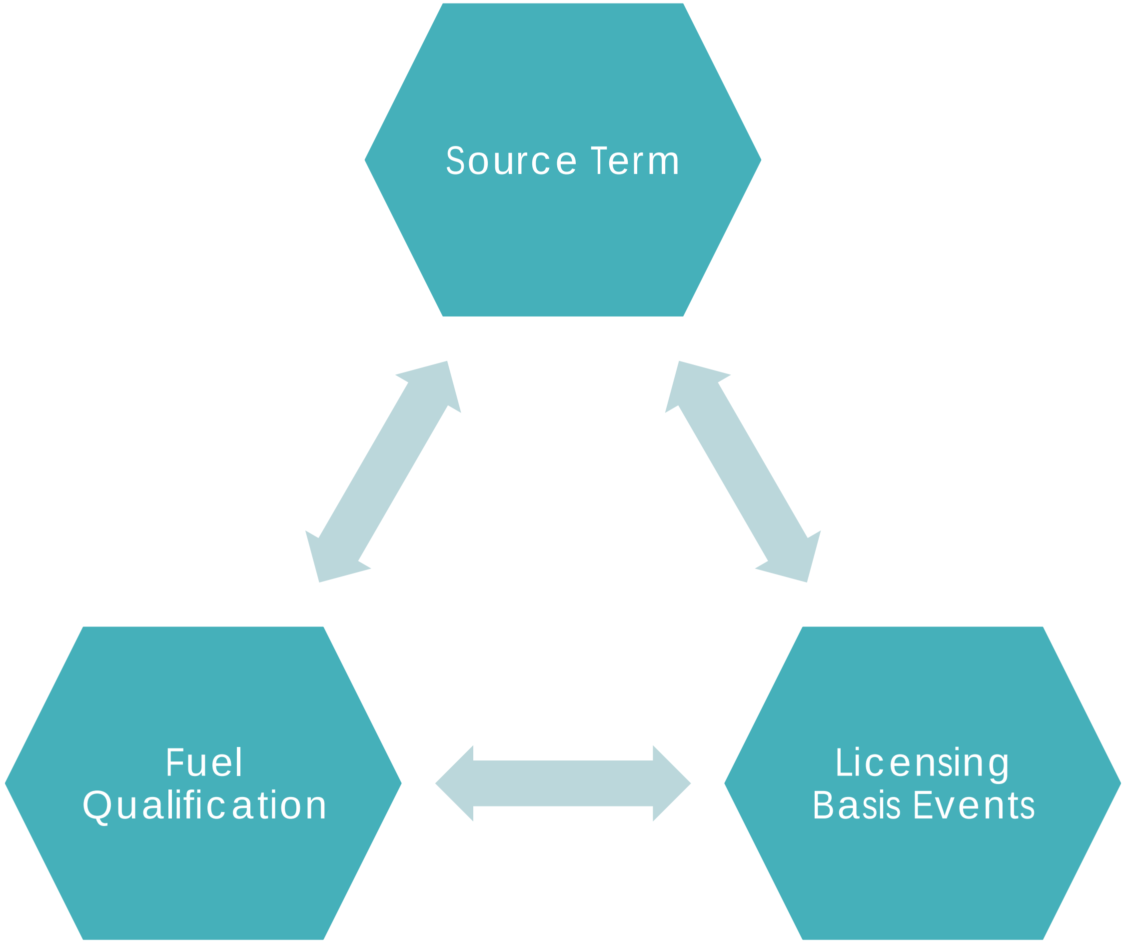
- SECY-92-092 (ML040210725) establishes requirements for advanced reactors to employ MST

1) The performance of the reactor and fuel under normal and off normal conditions is **sufficiently well understood** to permit a mechanistic analysis.

2) The transport of fission products can be **adequately modeled** for all barriers and pathways to the environs, including specific consideration of containment design.

3) The events considered in the analyses to develop the set of source terms for each design are selected to **bound severe accidents and design-dependent uncertainties**.

Fuel Salt Qualification is an Element of MSR Safety Evaluation



- DG-1353 or maximum hypothetical accident approach can be used to identify licensing basis events[1]
  - Accident progression models and tools
  - Barrier performance
- Advanced reactor siting criteria based upon radiological consequences from design-specific characteristics[2]
  - Bounding simplifications may be possible[3]

[1] Non-Light Water Review Strategy Staff White Paper Draft, ML19275F299,
[2] NRC Staff White Paper, Population-Related Siting Considerations for Advanced Reactors, ML19163A168
[3] ACRS Review of Draft SECY Paper, Population-Related Siting Considerations for Advanced Reactors, ML19277H031

Molten Salt Fuel Qualification

Pete Gaillard
Director, Regulatory Affairs
April 22, 2020

Today's Presentation

- Review Molten Salt Fuel Qualification
- Discuss the Regulatory Framework
- Describe how the Licensing Modernization Project (LMP) and Technology Inclusive Content of Application Project (TICAP) provide input to Molten Salt Fuel Qualification

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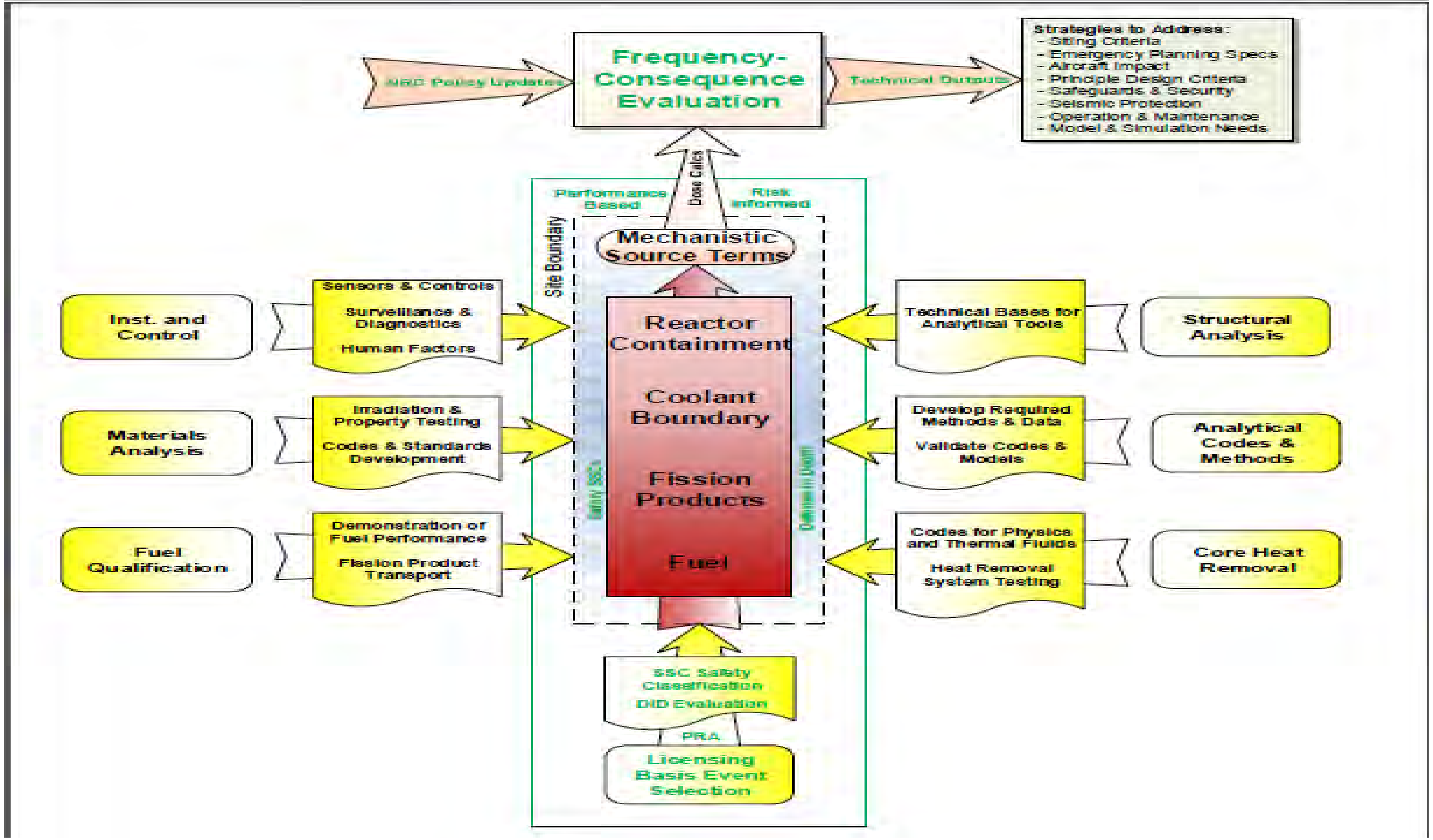
Fuel Qualification and LMP



Objective and Elements of Fuel Qualification

Fuel Qualification Objective:

- Demonstrate with high confidence that physical and chemical behavior of fuel is sufficiently understood so that it can be adequately modeled during both normal and accident conditions, reflecting the role of the fuel design in the overall safety of the facility.

Key Elements May Include:

- Regulatory Framework
- A Fuel Salt Property Database
- A Material Property Database

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Regulatory Framework

- NUREG 0800, Section 4.2 was written for Light Water Reactor (LWR) fuel
- The regulatory framework needs to be reconsidered for molten salt
- The evaluation of the regulatory framework will support fuel qualification by identifying licensing basis events (LBEs) and establishing acceptable fuel characteristics.
- The evaluation of the revised regulatory framework will benefit from LMP/TICAP input

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LMP/TICAP Input to Fuel Qualification

How does LMP relate to fuel qualification?

- LMP provides a systematic Risk Informed Performance Based (RIPB) option for selecting the required LBEs to be modeled to establish acceptable fuel specifications for bounding conditions
- LMP provides a process to help demonstrate reasonable assurance of adequate protection

How does TICAP add value to fuel qualification?

- TICAP provides focus on the safety case and information needed to sufficiently demonstrate reasonable assurance of adequate protection of public health and safety.

TerraPower

Summary

- The goal of Fuel Qualification is to demonstrate physical and chemical behavior of fuel is sufficiently understood so that it can be adequately modeled for normal and accident conditions, reflecting the role of the fuel design in the overall safety of the facility.
- The current regulatory framework for fuel needs to be reconsidered for molten salt
- LMP provides a systematic RIPB option for selecting the required LBEs
- TICAP provides focus on the safety case and information needed to be presented in the License Application

TerraPower

References

1. "An Approach to Fuel Development and Qualification", Douglas C. Crawford, et el.

2. ML20072M206, Draft MSR Fuel Salt Qualification Methodology 5Mar2020 version, Oak Ridge National Laboratory (ORNL) regarding molten salt reactor fuel qualification.

TerraPower