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Regulatory Perspective and Accident Management Procedure Influences on

Accident Monitoring Instrumentation Design Criteria

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IAEA/JNESO Workshop on Accident Monitoring Instrumentation
Tokyo, Japan
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Agenda

- Regulatory Perspectives and Historical Influences on Existing Accident Monitoring Design Criteria
- Overview of Pertinent USNRC Fukushima Lessons Task Force Initiatives Impacting Improved Accident Monitoring Capability
- Accident Management and Task Force Recommendation 8:
  Integration of On-site Emergency Response Processes--EOPs, SAMG's,and EDMGs
- Task Force Recommendation ACRS 2(e): Enhanced Reactor & Containment Instrumentation
- Coordination of Accident Monitoring Regulatory Framework with Results of Other Task Force Initiatives that Potentially Add New Accident Monitoring Instrumentation or New Design Criteria

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Regulatory & Historical Perspectives on

Accident Monitoring Instrumentation Design Criteria

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Regulatory Perspectives

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Definitions:

In the US nuclear regulatory arena the term "prevention" has historically been used to describe those activities and systems intended to prevent accidents (traditionally, design-basis accidents) from occurring. Examples of such activities and systems would include the design, implementation, and operation of Emergency Core Cooling Systems and other Essential Safety Feature Systems. Such systems are designed to prevent design-basis events from causing site radiological releases by keeping the reactor core from melting and maintaining the integrity of fuel cladding barriers.

In the same arena, the term "mitigation" is used to describe those activities and systems intended to keep fission products that would be released from a melted core away from the public.

Regulatory Perspectives

Defense-in-Depth:

The term "defense-in-depth" is a strategy applied to ensure public health and safety. It refers to a facility design and operation philosophy that is based on providing successive levels of protection such that public health and safety will not be wholly dependent upon any single element of the design, construction, operation, or maintenance of the facility.

There are multiple design and planning tactics which may be applied when implementing a defense-in-depth strategy.

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Regulatory Perspectives

Regulatory Principles:

Historical Regulatory Approach:

Consistency with the defense-in-depth philosophy is maintained if a reasonable balance is preserved among the functions of preventing (design basis) accidents that could result in core damage or barrier failure, and mitigating the consequences of such events.

Proposed (Post-Fukushima) Regulatory Approach:

Consistency with the defense-in-depth philosophy is maintained if a reasonable balance is preserved among a) the prevention of accidents (including beyond-design-basis accidents), b) the mitigation of accidents to prevent core damage and radioactive releases, and c) emergency preparedness to minimize public health consequences, if such releases occur.

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Regulatory Perspectives

Applicability of the Defense-in-Depth Principle Extends to:

• Design and Implementation of plant systems, including systems that respond to anticipated operational occurrences (AOOs), design-basis internally and externally-initiated events, and severe accidents;

• Normal, Abnormal, Emergency, and Severe-Accident Management Operating Procedures

•The bases for selection of alternative actions in Emergency Preparedness activities

• Underlying criteria used in the design of plant monitoring systems that aid the operator in conducting plant operations under all phases of operations

• Continued Maintenance of all the above

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Historical Perspective

Bases for Existing US Accident Monitoring Regulations

The TMI-2 Accident in March, 1979 significantly influenced the development of our current US accident monitoring criteria, which is based:

• In part, on **ANSI/ANS 4.5-1980**. “Criteria for Accident Monitoring functions in Light-Water-Cooled Reactors”

• In part, on USNRC **Regulatory Guide 1.97**, Revs 2, 3, and 4

• In part, on **NUREG-0737** "Clarification of TMI Action Plan Requirements,"

• In part, on **IEEE Std 497** “Standard Criteria for Accident Monitoring Instrumentation for Nuclear Power Generating Stations,” Revisions 1981, 2002, 2010

• In part, on other regulatory and industry standard influences (e.g., **NUREG-0737 Supplement 1** (Emergency Preparedness), **NUREG-0700/0711** (Human Factors Considerations)

Historical Perspective

Bases for Existing US Accident Monitoring Regulations

Current Accident Monitoring Regulatory Guidance is still heavily influenced by the historical application of the defense-in-depth principle, and by the original assumptions included in ANSI/ANS-4.5-1980, which has since been withdrawn by ANS.

Examples:

- Accident Time Phases of Interest
- Purpose of Type A Parameters
- Source Term Assumptions

Historical Perspective

Bases for Existing US Accident Monitoring Regulations
(continued)

Accident Time Phases of Interest

ANS 4.5-1980 points to two phases: (to help define design criteria)

I. "Initial portion of accident"

II. "Stable, long-term cooling up to the time where personnel access to commence inspection, repair, or replacement activities is possible"

Underlying assumption is that significant core damage has not occurred.

IEEE 497 improves this definition of phases of interest, but does not apply the assumption of significant core damage in its estimates of required operating time. Reference is made to plant licensing basis documentation, which for current operating plants do not address significant core damage.

Historical Perspective

Bases for Existing US Accident Monitoring Regulations (continued)

Purpose of Type A Parameters

ANS 4.5-1980: "Those variables that provide information to permit the operator to take the pre-planned manual actions to accomplish and maintain safe plant shutdown for design basis accident events.

IEEE 497-2010: "Those variables…a) take specific planned manually-controlled actions for which no automatic control is provided and that are required for safety systems to perform their safety functions…b) …and that are required to mitigate the consequences of an anticipated operational occurrences…"

Both versions have an underlying assumption that no significant core damage has occurred due to a beyond-design-basis occurrence.

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Historical Perspective

Bases for Existing US Accident Monitoring Regulations

Source Term Assumptions:

In defining the requirements for Type C variables, **ANS 4.5-1980** states that chosen measurements “shall detect the possibility of a gross breach of one or more fission product barriers (i.e., an in-core fuel clad breach capable of releasing more than 1% of the fuel clad gap and plenum activity for the core.)”

Such a release should be based on 10 CFR Part 100 limits at the site boundary using TID-14844 source terms—the ranges established for Type C variables are not mechanistically related to a postulated accident scenario.

IEEE 497-2010: “The range … shall be established to cover the accidents identified in the plant licensing basis documents. These variables shall have an extended range and address a source term that *considers* a damaged core”

Historical Perspective

Bases for Existing US Accident Monitoring Regulations (continued)

Source Term Assumptions (approximates)

TID-14844: 100% of Noble Gases, 50% Iodine released as a gas, 1% of all radionuclides as particulates. (Includes 1% Cesium release)--Instantly available in the containment. (Based on early-1970s Reactor Safety Study solely for the purpose of estimating potential health consequences to public)

Newer studies indicate different release scenarios:

Example **NUREG-1465:** Indicates that there are 4 phases of release: Early gap release, In-vessel release, Ex-vessel release, Late in-vessel release (Includes 30% Cesium in the releases). (Based on STCP and MELCOR)

Historical Perspective

Examples of Studies that Serve to Challenge the Assumptions Underlying Current Accident Monitoring Regulatory Guidance

NUREG-1465: Accident Source Terms for Light-Water Nuclear Power Plants (1995)

NUREG-1150: Severe Accident Risks: An Assessment for Five U.S. Nuclear Power Plants (1990)

NUREG/CR-5869: Identification and Assessment of BWR In-Vessel Severe Accident Mitigation Strategies (1992)

NUREG/CR-7110: State-of-the-Art Reactor Consequence Analysis Project (2012)

SAND2012-6173: Fukushima Daiichi Accident Study (2012)

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Near-Term Task Force

Post-Fukushima Task Force Findings:

- Develop a set of Recommendations for continuing the USNRC Defense-in-Depth Policy, but modified as necessary by state-of-the-art probabilistic risk assessment techniques, to serve as the primary organizing principle of the USNRC regulatory framework.

- The application of defense-in-depth philosophy can be strengthened by including explicit requirements to address beyond-design-basis events.

- Take a balanced approach to defense-in-depth as applied to low-likelihood, high-consequence events resulting from severe natural phenomena.

Near-Term Task Force

Task Force Recommendations that could Impact Accident Monitoring Design Criteria:

- Require Updated Estimates (re-evaluation) of Natural Hazard Events (in US—primarily seismic and flooding)

- Strengthen Station Black-out Mitigation Capability

- Require Reliable Hardened Vent Capability for Mark I and Mark II Primary Containments

- Identify Insights regarding Hydrogen Control, enabling the prevention of explosions through preventative and mitigative means

Near-Term Task Force

Task Force Recommendations that could Impact Accident Monitoring Design Criteria:

- Enhance Spent Fuel Pool Make-up Capability and Instrumentation

- Strengthen and Integrate Onsite Emergency Response Capabilities (Chris Cowdrey to discuss in detail)

- Develop plans for prolonged station blackout and multi-unit events

- Enhance Emergency Preparedness Planning to support evacuation decision-making, on-site and off-site radiation monitoring, and public education

Near-Term Task Force

Task Force Recommendations that could Impact Accident Monitoring Design Criteria:

- Strengthen Regulatory Oversight of Licensee Safety Performance, focusing on defense-in-depth requirements consistent with the modified framework.
- The modified framework should be based on the defense-in-depth philosophy supported by PRA techniques, strengthened by establishing appropriate levels of defense-in-depth to address requirements for “extended” design-basis events. Such a strengthening would provide a greater emphasis on beyond-design basis and severe accident mitigation.

USNRC Lessons Learned Task Force
Near-Term Recommendation 8
Onsite Emergency Response Capabilities

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NTTF Recommendation 8

The Fukushima Near-Term Task Force (NTTF) Recommendation 8 endorsed the strengthening and integration of emergency operating procedures (EOPs), severe accident management guidelines (SAMGs), and extensive damage mitigation guidelines (EDMGs) using the rulemaking process.

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NTTF Recommendation 8

- In SECY-11-0037 the NRC staff recommended that the NRC, as a near-term action, undertake regulatory actions to resolve NTTF Recommendations 8.1, 8.2, 8.3 and 8.4 which include:
  - Issue an Advanced Notice of Proposed Rulemaking (ANPR) to engage stakeholders in rulemaking activities associated with the methodology for integration of onsite emergency response processes, procedures, training and exercises.
  - Interact with stakeholders to inform the modification of EOP generic technical guidelines to include guidance for SAMGs and EDMGs in an integrated manner and to clarify command and control issues as appropriate.

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Current Regulatory Approach

- EOPs address design basis accidents and are required by 10 CFR 50, Appendix B, Criterion V and Technical Specifications.
- SAMGs are a voluntary industry initiative that provide guidance for events that progress beyond design basis assumptions.
- Post 9/11 requirements of 10 CFR 50.54(hh)(2) resulted in the development of EDMGs to address large area emergencies.

Current Status

Onsite Emergency Response Capabilities

- The existing accident mitigating procedures (EOPs, SAMGs and EDMGs) have been developed as separate initiatives with varying degrees of integration between procedures.
- The format and procedure control of SAMGs differ throughout the industry.
- Industry approaches to training, qualification and exercises for SAMGs and EDMGs are not standardized.

NTTF Recommendation 8 Objectives

- Ensure that effective transitions are developed between the various accident mitigating procedures so that overall strategies are coherent and comprehensive.
- Ensure that command and control strategies for large scale events are well defined in order to promote effective decision-making at all levels and develop organizational flexibility to respond to unforeseen events.
- Ensure that key personnel relied upon to implement these procedures and strategies are trained, qualified and evaluated in their emergency response roles.
- Ensure accident mitigating procedures, training and exercises are standardized throughout the industry.

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NTTF Recommendation 8 Objectives

Ultimately, NTTF Recommendation 8 is the opportunity to provide reasonable assurance that if a beyond design basis event occurs, that the strategies for severe accident mitigation (those developed as a result of NTTF recommendations and previous regulatory efforts) can be effectively implemented.

Regulatory Approach

- Use standard Rulemaking process to address Recommendation 8.
- No current plans for an initial Commission Order – rulemaking must be responsive to the strategies developed as a result of other NTTF recommendation efforts.
- Solicit stakeholder input for the development of an approach to integrated onsite emergency response capability.
- Encourage Industry Owners Groups to lead the effort to standardize and integrate accident mitigating procedures.
- Interact with other NTTF recommendation teams to ensure that approach is well coordinated and final product is coherent and comprehensive.

Focus Items
Accident Mitigating Procedures

- Identify current level of integration between accident mitigating procedures.
- Establish effective transitions to enhance procedure integration.
- Determine best approach for upgrading and standardizing technical guidelines.
- Extend guidance to address strategies developed as a result of other NTTF efforts.
- Prevent any adverse impact on current EOP strategies and training requirements.

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Focus Items
Accident Mitigating Procedures

Identify current level of integration between accident mitigating procedures.

- Transition from EOPs to SAMGs currently based primarily on CETs.
- Other indications used to confirm the onset of core damage - RCS level, RCS pressure, containment pressure, containment hydrogen concentration, RCS injection flow rate, nuclear instrumentation and high range radiation monitors.

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Focus Items
Accident Mitigating Procedures

Establish effective transitions to enhance procedure integration. Identify instrumentation requirements to inform the transition points to various mitigating strategies.

- Transitioning to alternate core injection methods, including seawater injection
- Initiating containment venting
- Flooding containment
- Identifying RPV breach criteria
- Initiating alternate make-up to spent fuel pool
- Informing emergency plan decisions

Focus Items
Accident Mitigating Procedures

Essential PWR Parameters

- Reactor
  - RCS Level
  - RCS Pressure
  - Reactor Power
  - RCS Injection Flow
  - Core Exit Temperatures
- Containment
  - Containment Pressure
  - Containment Temperature
  - Containment Water Level
  - H2/O2 Concentration
  - Radiation Levels
  - Containment Injection Flow
  - Containment Spray Flow

Essential BWR Parameters

- Reactor
  - RPV Water Level
  - RPV Pressure
  - Reactor Power
  - RPV Injection Flow
  - RPV Metal Temperatures
- Primary Containment
  - Containment Pressure/Temperature
  - Containment Water Level
  - H2/O2 Concentration
  - Radiation levels
  - Containment Injection Flow
  - Drywell Spray Flow
- Secondary Containment
  - Containment Temperature
  - Water level
  - Radiation Level

Focus Items

Accident Mitigating Procedures

Additional parameters to consider:

- RPV temperatures (PWRs)
- Secondary H2 concentration (BWRs)
- Drywell water levels (BWRs)
- Additional nuclear instrumentation
- Offsite radioactivity release rate
- Spent fuel pool parameters

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Focus Items
Command and Control

- Establish a command and control strategy to address events that progressively increase in severity past design basis assumptions.
- Ensure a formal approach to defining roles and responsibilities as they are transferred.
- Match the command and control strategy with the enhanced capabilities resulting from NTTF efforts.
- Ensure the command and control strategy is standardized throughout the industry.

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Focus Items
Command and Control

The effectiveness of a command and control structure is dependent on receiving and communicating accurate plant information.

- Expected accuracy of indications added to mitigation procedures
- Diversity of indications to support operational decisions
- Instrumentation to confirm expected response from mitigating strategies
- Remote monitoring of key parameters

Focus Items
Training and Qualifications

- Identify key personnel responsible for implementing accident mitigating strategies.
- Develop an appropriate level of continuing training requirements and qualifications for key personnel.
- Standardize continuing training requirements.
- Identify additional knowledge requirements for licensed operators.

Focus Items

Training and Qualifications

Develop an appropriate level of continuing training requirements and qualifications for key personnel.

- Understanding limitation of certain instruments
- Developing diagnosis skills based on diverse set of indications
- Understanding of the maintenance and operating procedures for severe accident instrumentation

Focus Items
Exercises

Identify requirements for exercises to ensure onsite emergency response capabilities can be evaluated.

- Develop drills that test new mitigating strategies
- Define periodicity within current 8-year cycle
- Determine the appropriate length/depth of an onsite emergency response capability drill
- Identify key evaluation parameters to assess performance

Focus Items
Exercises

Identify requirements for exercises to ensure onsite emergency response capabilities can be evaluated.

- Develop understanding of instrument response during severe accidents
- Apply this understanding to exercises and drills to develop more realistic scenarios

Questions

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ACRS Recommend. 2(e)

Enhanced Reactor and Containment Instrumentation

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ACRS Recommend. 2(e)

Background:

"Selected reactor and containment instrumentation should be enhanced to withstand beyond-design-basis accident conditions"

- Current Reactors –Implement Post-TMI instrument recommendations to address design basis accidents

- New Reactors—Implement Post-TMI instruments plus describe severe accident capabilities

ACRS Recommend. 2(e)

Dependencies on Existing Near-Term Actions

- Seismic and Flooding Evaluations
- SBO Rulemaking
- Mitigating Strategies Order
- Spent Fuel Pool Instrumentation Order
- EOPs/SAMGs/EDMGs Integration Rulemaking
- Reliable Hardened Vent Implementation

ACRS Recommend. 2(e)

Staff Action Plan

- Ensure that the potential need for enhanced reactor, containment, and SFP instrumentation is being adequately considered during the other Tier 1 Near Term Task Force actions.

- Review/participate in domestic & international efforts to study/ develop severe accident information needs and identify any monitoring instrumentation gaps. (This is one of those occasions.)

- Gather and review information results from higher Tier actions.

- Develop a regulatory framework for enhanced reactor and containment instrumentation.

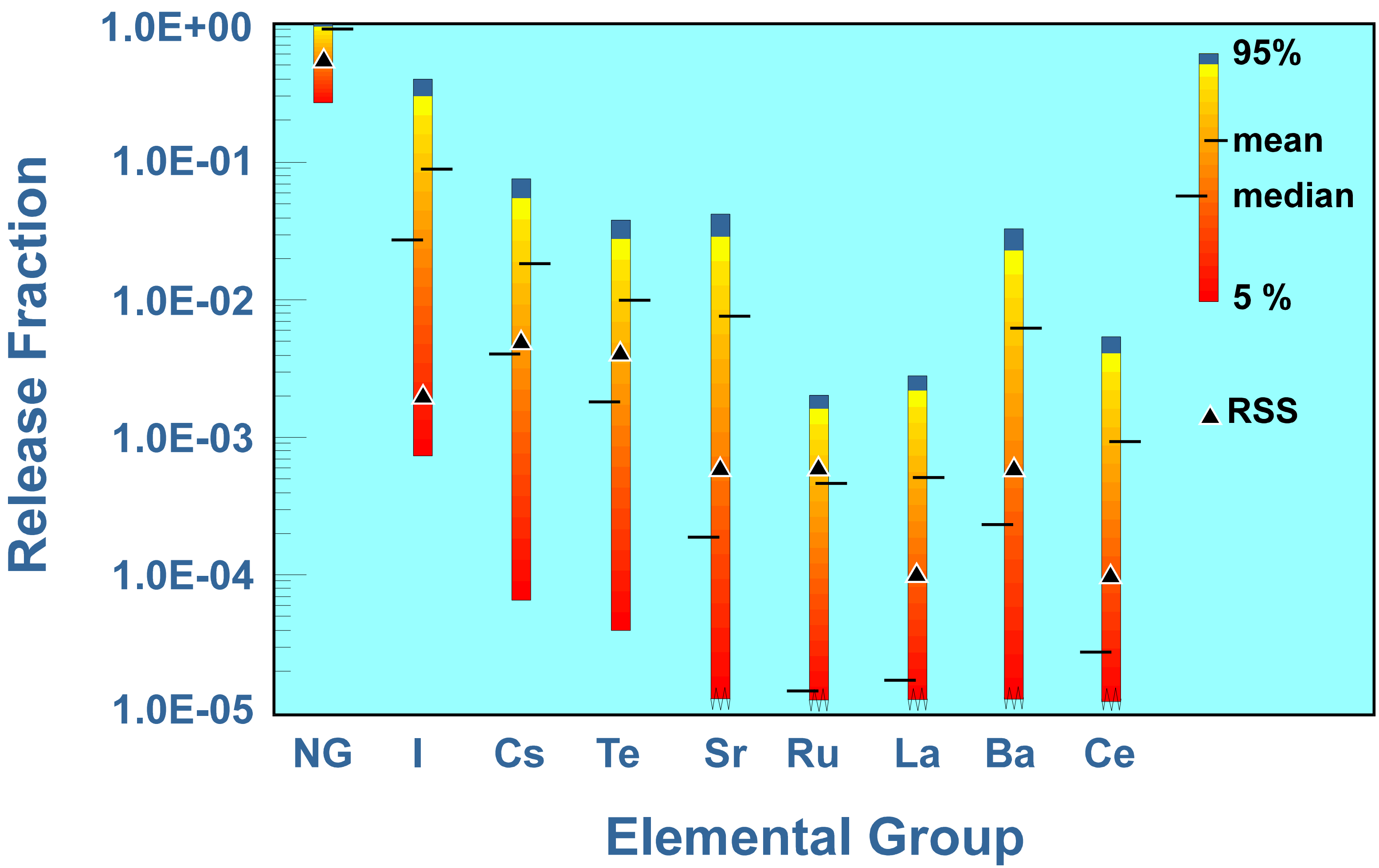
ACRS Recommend. 2(e)

Questions

Back-up Slides

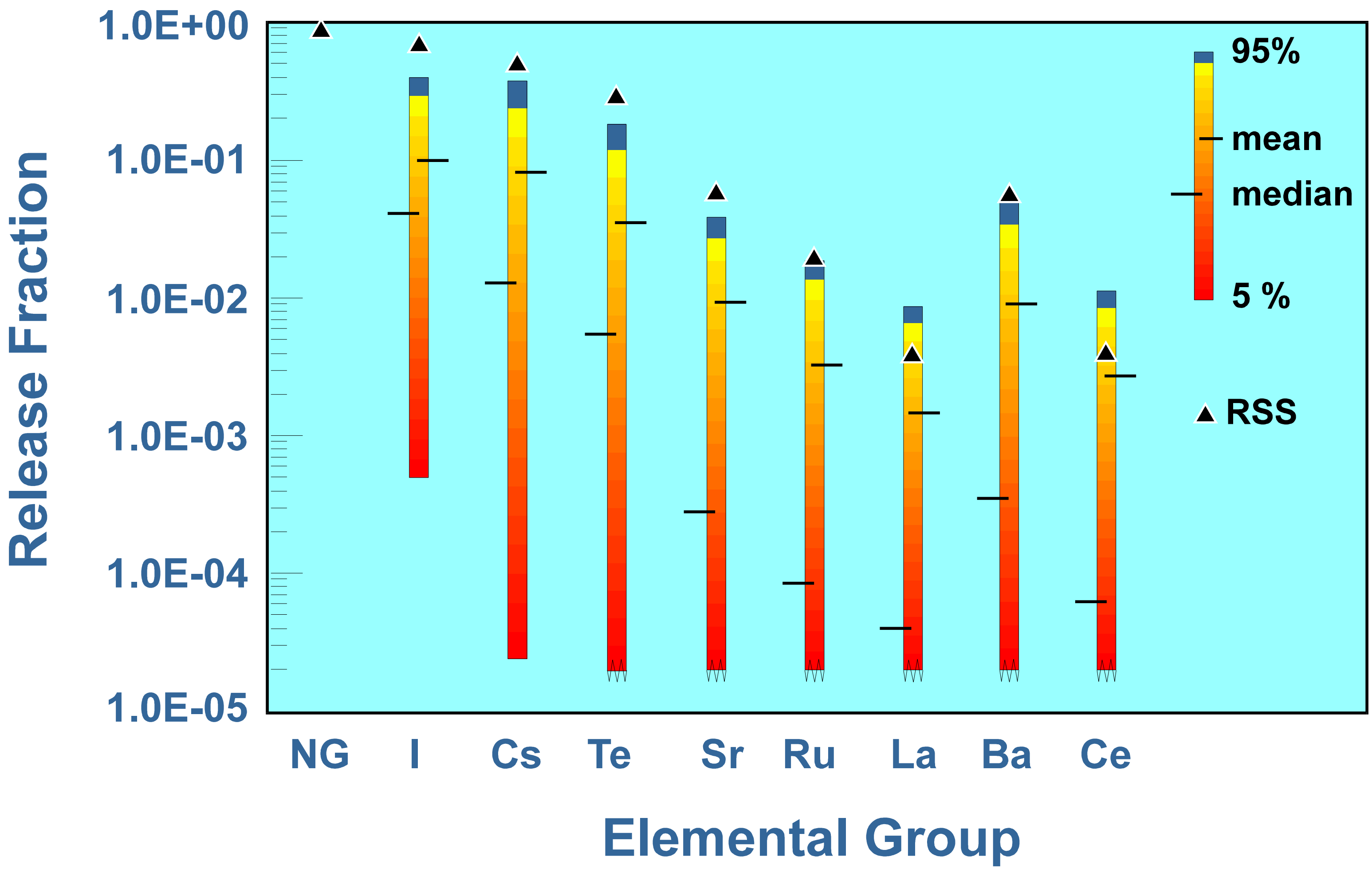
Source Term Uncertainty

- Not considered in 1975 reactor Safety Study
  - Nine PWR source term bins (PWR 1 to PWR 9)
  - Five BWR source term bins (BWR 1 to BWR 5)
- Treated in NUREG-1150
- Uncertainty large even given a specific set of accident progression events



Comparison of NUREG-1150 source terms with Reactor Safety Study (PeachBottom) bin BWR4

5.1.5 ¶ 2a



Comparison of NUREG-1150 source terms with Reactor Safety Study (Surry) bin PWR2

Licensing Source Term

- Release to the containment
- Used for site suitability analysis
- Environmental qualification of containment equipment, etc.
- Licensees estimate mitigation using engineered safety systems

Most Current Plants Licensed to The TID-14844 Source Term

- 100% noble gases
- 50% of iodine as a gas
  - Half of this allowed to deposit naturally
- 1% of all radionuclides as particles

All instantly available in containment.

- timing impacts safety systems

Modern Source Term to the Containment

- Four phases
  - Gap release: venting gap inventory upon clad rupture
  - Invessel release: fuel degradation & melting
  - Exvessel release: DCH, melt-concrete, etc.
  - Late invessel release: revaporization
- Usually only first two used to assess site suitability and mitigation capabilities
- Time dependence especially important