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SESSION 1-8

COMMONLY IMPLEMENTED RISK-INFORMED APPLICATIONS

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RISK-INFORMED REGULATION SEMINAR
Mexico City, Mexico August 27-31, 2012

TOPICS

- Risk-Informed Applications
  - Risk-Informed Inservice Inspection (RI-ISI)
  - Risk-Informed Technical Specification (RI-TS)
    - Example of Risk-Informed Technical Specification

- Non-Risk-Informed Applications that use Risk Information
  - Extended Power Uprate (EPU)
  - License Renewal Severe Accident Mitigation Alternatives (SAMA)

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Risk-Informed Inservice Inspection (RI-ISI)

- One of the most successful risk-informed applications in the US
- Nearly all licensees have implemented RI-ISI
  - 101 out of 104 plants

Risk-Informed Inservice Inspection (RI-ISI)

- 10 CFR 50.55a(g) requires that Inservice Inspection (ISI) of the American Society of Mechanical Engineers (ASME) Code Class 1, 2, and 3 components be performed in accordance with Section XI of the ASME Boiler and Pressure Vessel Code, "Rules for Inservice Inspection of Nuclear Power Plant Components" and applicable addenda, except where specific written relief has been granted by NRC
- 10 CFR 50.55a(a)(3) states in part that alternatives to the requirements of paragraph (g) may be used, when authorized by the NRC, if the proposed alternatives would provide an acceptable level of quality and safety or if the specified requirement would result in hardship or unusual difficulty without a compensating increase in the level of quality and safety.

RI-ISI Guidance

- Regulatory Guide 1.178 used in conjunction with Regulatory Guide 1.174 for NRC position on RI-ISI programs
- NRC approved well defined generic methodologies via Topical Reports (WOG and EPRI):
  - SER for WOG Topical Report (WCAP-14572) issued in December 1998.
  - SER for EPRI Topical Report (TR-112657) issued in October 1999.
- The WOG and EPRI methodologies are generally similar but use different techniques at different stages
- Beginning in 2007, a simplified method described in ASME Code Case N-716, "ASME Issued Code-Case N-716, "Alternative Piping Classification and Examination Requirements," has been proposed and accepted at several sites

RI-ISI Processes

WOG and EPRI RI-ISI PROCESS OVERVIEW

- Divide Systems into Piping Segments
- Evaluate Consequences of Each Segment's Failure
- Determine Failure Potential of Each Segment
- Categorize Risk Significance of Each Segment
- Select Welds and Elements for Inspection
- Assess Impact on CDF and LERF
- Demonstrate Conformance with RG 1.174

RI-ISI Processes

- ASME Code-Case N-716, "Alternative Piping Classification and Examination Requirements."
  - Assigns high safety significance (HSS) classification to welds based on experience from 50+ RI-ISI programs, e.g.,
    - All Class 1 (except very small lines)
    - Well defined portions of some Class 2 and 3 systems
    - High energy piping in Break Exclusion Region
    - Any piping that PRA screening analysis identifies as HSS
  - PRA screening analysis is well described in the ASME PRA Standard's flooding analysis section
  - Impact assessment on CDF and LERF is retained

RI-ISI Processes

- ASME Issued Code-Case N-716, "Alternative Piping Classification and Examination Requirements."
  - Provides guidelines for selecting examination locations from the HSS welds
    - All degradation mechanisms in the HSS population should be identified
    - All identified degradation mechanisms should be included in the examined population
  - A minimum of 10% of HSS welds should be examined

RI-ISI Processes

- ASME Issued Code-Case N-716, "Alternative Piping Classification and Examination Requirements."
  - By relying on the ASME PRA Standard's flooding methodology, PRA technical adequacy reviews can take advantage of "traditional" technical adequacy reviews
  - Specifying a minimum of 10% locations must be examined provides a well defined result
  - Recent submittal of EPRI Topical describing in detail PRA technical adequacy requirements may enable the Staff to endorse a Code Case in RG 1.147 so that method becomes part of the Code (no relief request needed)

RI-ISI Summary

- ASME RI-ISI Code-Cases and Voluntary Appendix R
  - All Risk-informed applications require the technical adequacy of the PRA analysis be demonstrated
  - All proposed methods except for N-716 rely on a RI-ISI specific PRA analysis (i.e., performed solely to support RI-ISI)
  - N-716 relies on the flooding analysis described in ASME/ANS RA-Sa-2009 which simplifies the demonstration of PRA technical adequacy
- Living RI-ISI
  - Current RI-ISI is not endorsed as part of the AMSE code by the NRC – so licensees must request relief from code requirements to use it
  - Relief is generally granted only for the 10-year interval – so licensee must request relief again for each new interval
  - The staff only grants a new relief request after the licensee demonstrates that it has updated its analyses
  - The staff anticipates that any endorsed ASME code change that includes RI-ISI will include a provision for periodic update of the underlying analysis

RI-ISI focus inspections at highest risk locations

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Risk-Informed Technical Specification (RI-TS)

- One of the most successful risk-informed applications in the US
- All licensees have implemented some aspect of RI-TS

Risk-Informed Technical Specification (RI-TS)

- General Philosophy: Apply risk insights from PRA to establish and manage plant operational limits and requirements
- Regulatory Guide 1.177 used in conjunction with Regulatory Guide 1.174 for NRC position on RI-ISI programs
- Joint Industry/NRC initiatives to establish methods to apply PRA to Technical Specifications
- Benefits:
  - Improved safety focus on risk-significant items/issues
  - Flexibility/relaxation of requirements when appropriate

RI-TS Initiatives

- Initiative 1: Modified End States – justify remaining in a mode other than cold shutdown when equipment is inoperable
- Initiative 2: Missed Surveillance Test – justify additional time to complete a missed test
- Initiative 3: Modify existing mode restraint logic to allow entry into higher mode limiting conditions for operation (LCOs)
- Initiative 4a: TS Completion Time (CT) Extensions – justify extensions of selected system CTs
- Initiative 4b: Risk Managed TS – allow flexible CTs based on configuration-specific risk calculations and risk management actions using NRC approved methodology

RI-TS Initiatives

- Initiative 5: Extension of Surveillance Test Intervals - staff approved risk-informed methodology to allow licensee control of test intervals
- Initiative 6: Modification of LCO 3.0.3 (shutdown) – changes to required actions and times
- Initiative 7a: Snubbers - delay LCOs entry due to removal of snubbers for testing/maintenance
- Initiative 7b: Hazard Barriers - delay LCO entry due to removal of hazard barriers to support maintenance
- Initiative 8: Removal of non risk-significant LCOs from TS scope

RI-TS Initiative 1
End States

- Effect: Allow repair in most risk beneficial manner (e.g., hot shutdown instead of requiring transition to cold shutdown)
- Basis: generic analysis of preferred mode for repair of inoperable equipment
- Status: CE and BWR Approved Westinghouse and B&W under review

RI-TS Initiative 2
Missed Surveillances

- Effect: Extension of flexibility granted in Generic Letter 87-09, allow up to one surveillance interval to make up inadvertent missed/incomplete surveillance
- Basis: Infrequent use, likelihood that equipment is operable, entry into corrective action program, assess and manage risk of delay as extension of (a) (4) program (treat as emergent condition)
- Status: Approved; > 95% plants have adopted

RI-TS Initiative 3
Mode Flexibility

- Effect: Extension of flexibility granted in Generic Letter 87-09, allow mode transition up in power with inoperable equipment, relying on compliance with TS actions of higher mode
- Basis: Infrequent use, generic risk analysis ruling out some transitions, 50.65(a)(4) assessment and management of risk, oversight of 50.65(a)(4)
- Status: Approved; over 50% of plants adopted

RI-TS Initiative 4a/b Completion Times

- Effect: Extend completion time from a nominal, current TS value up to an acceptable value.
- Basis: Guidance available in RG 1.174 and 1.177 for single RI-TS Completion Time changes. Additional guidance developed for overall risk managed TS, to include: approved decision-making process; implementation guidance; requirements for PRA technical adequacy; quantitative configuration & cumulative risk metrics.
- Status: Multiple single RI-TS changes at most plants,

Initiative 5b
Surveillance Frequencies

- Effect: Requirement to perform surveillance remains in TS, frequency adjusted outside TS in TS program using staff-approved methods adopted by License Amendment, must satisfy both quantitative & qualitative criteria.

- Basis: PRA technical adequacy consistent with the requirements of Regulatory Guide 1.200.

- Status: Approved

Initiative 6
Shutdown Tracks

- Effect: Risk-inform shutdown completion times for loss of function within LCO

  (adjust completion times for LCO 3.0.3 shutdown)

- Basis: CE quantitative bounding risk analysis for specific technical specifications

- Status: CE topical review completed

Initiative 7
Support Equipment Impact

- Effect: Allow a TS train to be considered operable up to a maximum time with degraded non-TS design support features (barriers and snubbers)
- Basis: Generic calculation showing low risk due to low initiator frequency (internal flood, seismic event)
- Status: Approved

Initiative 8
TS Scope

- Effect: (a) Allow relocation of LCOs not meeting any 50.36 criteria, including criterion on risk significance, (b) Limit scope of TS to risk-significant SSCs
- Basis: Initiative 8a would review TS to remove systems that were included solely because they were judged risk significant at one time and have now been shown by analysis not to be. Initiative 8b would make the scope of technical specifications depend only on risk significance.
- Status: Awaiting Industry submittal. 8b requires rulemaking

Risk-Informed Technical Specifications

- Each initiative can involve some combination of:
  - Topical Report approving the generic change
  - Standard Technical Specification change proposal with a Technical Specification Task Force designator
  - Pilot plant submittal to test the change
  - A Consolidated Line Item Improvement Process (CLIIP) package
    - Described in NRC Regulatory Issue Summary 2000-06, "Consolidated Line Item Improvement Process for Adopting Standard Technical Specifications Changes for Power Reactors," for reviewing and implementing improvements to the Standard Technical Specifications

RI-TS

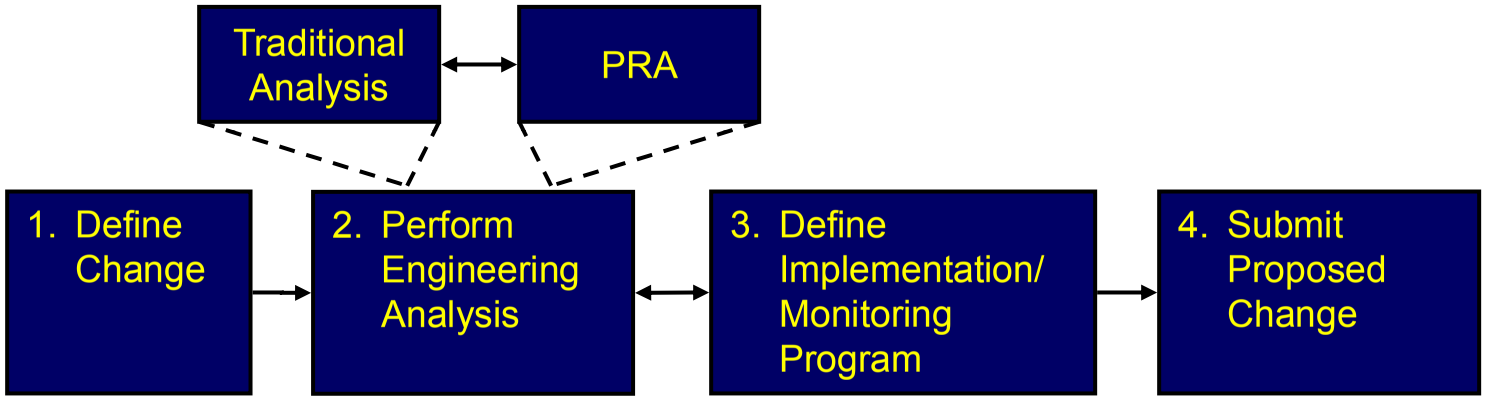
- Challenges:
  - Establishing the appropriate level of PRA quality to support each application
  - Scope of PRA models needed for specific changes
    - e.g., lack of detailed fire models may make some applications not possible
  - Addressing model assumptions and uncertainties

Example Risk-Informed Technical Specification License Amendment Request

- Request: Extend the current Technical Specification (TS) emergency diesel generator (EDG) Completion Time (CT) from 3 days to 14 days
  - Allows extended maintenance at-power instead of during refueling outage (can be outage critical path)
- Risk-informed license amendment, so the licensee referenced:
  - RG 1.174, “An Approach for Using PRA in Risk-Informed Decisions on Plant-Specific Changes to the Licensing Basis”
  - RG 1.177, “An Approach for Plant-Specific, Risk-Informed Decisionmaking: Technical Specifications”

License Application

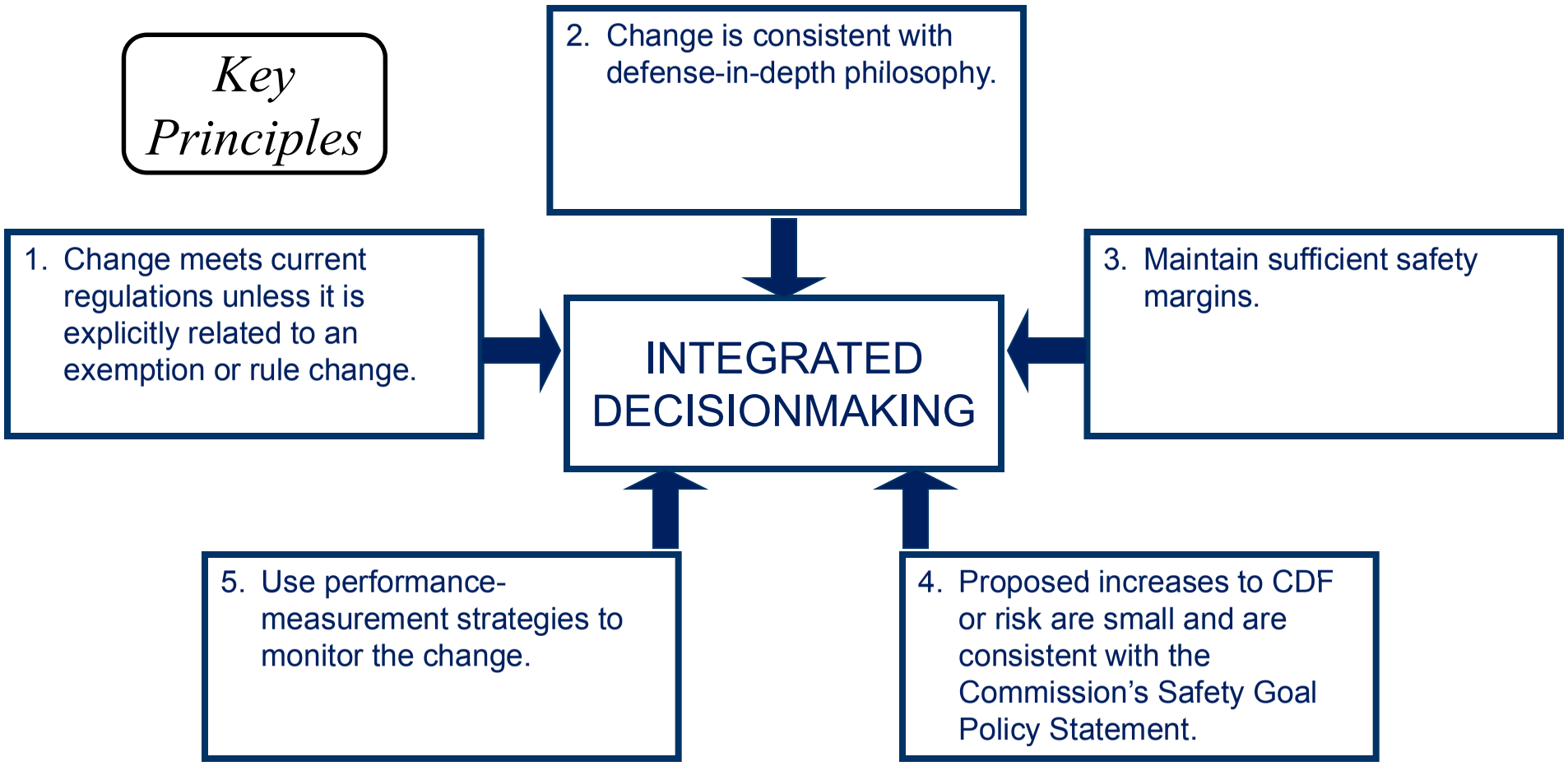
- Process for risk-informed license amendment requests:



- Uses the 5 key principles
- Risk acceptance guidelines

* RG 1.174, "An Approach for Using Probabilistic Risk Assessment in Risk-Informed Decisions on Plant-Specific Changes to the Licensing Basis"

Address 5 Key Principles



(Source: RG 1.174, 11/02)

Example Risk-Informed Technical Specification License Amendment Request

- Licensee submittal
  1. List of applicable regulations and how they would continue to be met
  2. Impact of the change on defense in depth
  3. Impact of the change on safety margins
  4. Risk assessment
  5. Performance measurement strategies

- Deterministic reviewers looked at # 1, 2, 3, & 5
- PRA reviewers looked at # 4 & 5

Example Risk-Informed Technical Specification License Amendment Request

- Part 1: Applicable Regulations
  - Licensee confirmed that the change meets the applicable regulations:
    - GDC 17, Electric Power Systems
      - Onsite and offsite electric power systems will still provide capacity and capability to assure fuel and RCS design limits are not exceeded and vital functions are maintained
    - GDC 18, Inspection and Testing of Electric Power Systems will still be met
    - 10 CFR 50.63 – Station Blackout coping analysis not impacted
    - 10 CFR 50.65 – Will satisfy current Maintenance Rule reliability and availability goals

Example Risk-Informed Technical Specification License Amendment Request

- Part 2: Defense in Depth
  - The licensee stated that there is no actual impact on defense in depth as a result of the change:
    - Fission product barriers not impacted
    - Equipment redundancy not impacted
    - Current license allows a period of time when the plant does not meet the single failure criterion
      - Requested change involves only the extension of the time period

Example Risk-Informed Technical Specification License Amendment Request

- Part 3: Safety Margins
  - RG 1.177 states that sufficient safety margins are maintained when:
    - Applicable industry codes and standards are met
    - Safety analysis acceptance criteria in the UFSAR are met
  - The licensee states that extending the EDG CT:
    - Does not modify or affect compliance with any industry standards
    - Does not reduce requirements for redundant equipment to be operable during the extended CT
    - Sufficient redundancy will be maintained to ensure the accident analyses in the Updated FSAR remain valid

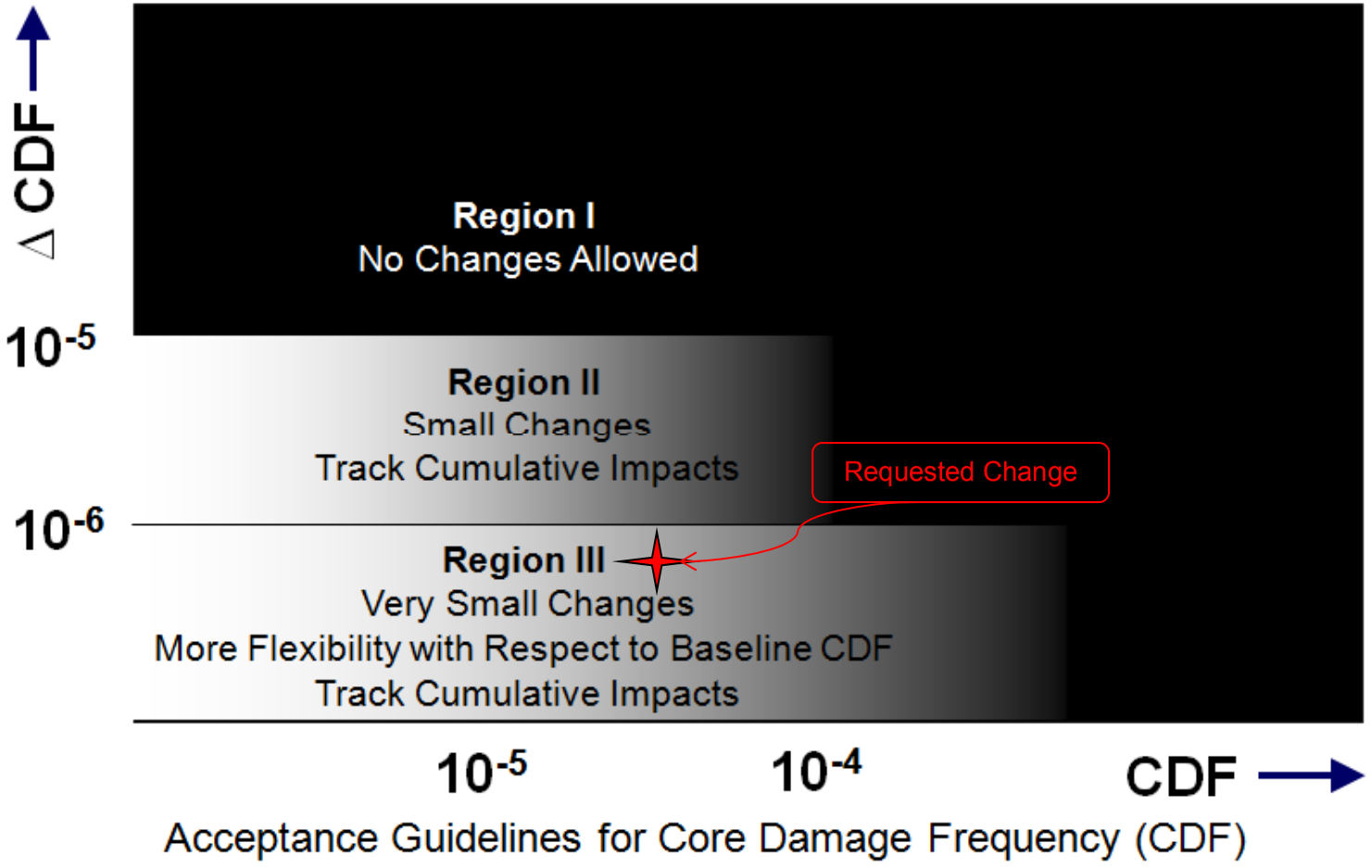
Example Risk-Informed Technical Specification License Amendment Request

- Part 4: Risk Assessment
  - RG 1.177 3-tier approach:
    - Assess risk, both average and configuration-specific
    - Preclude potentially high-risk plant configurations
    - Have adequate programs/procedures in place to
      - identify risk-significant plant configurations resulting from maintenance or other operational activities
      - take appropriate compensatory measures to avoid such configurations

Example Risk-Informed Technical Specification License Amendment Request

- Part 4, Tier 1 – Assess Risk
  - Technical adequacy of the PRA for this request
    - Model scope
    - Industry peer review
    - Conformance to RG 1.200
  - Evaluation of the PRA results and insights for this request
    - Compare impact on risk to acceptance guidelines of RG 1.174 and, since this is a TS change, RG 1.177

Example Risk-Informed Technical Specification License Amendment Request



Example Risk-Informed Technical Specification License Amendment Request

- Part 4, Tier 2 – High Risk Configurations
  - Licensee identified, up-front, potentially high-risk plant configurations or activities when the proposed CT is entered
  - Licensee imposed appropriate restrictions on these configurations or activities associated with the CT extension are in place

Example Risk-Informed Technical Specification License Amendment Request

- Part 4, Tier 3 – Risk Management Program
  - The licensee stated that its Maintenance Rule (a)(4) program satisfies the intent of Tier 3 because the licensee:
    - Assesses and manages risk of equipment removed from service prior to or during the proposed extended AOT period
    - Identifies risk-significant plant configurations resulting from maintenance or other operational activities
    - Takes appropriate compensatory measures
  - Reviewers must determine whether the (a)(4) program meets the intent of RG 1.177 Tier 3.

Example Risk-Informed Technical Specification License Amendment Request

- Part 5: Performance Measurement
  - The licensee should ensure that when equipment does not meet its performance criteria, the evaluation required under the Maintenance Rule (MR) includes prior related TS changes in its scope
  - Licensee stated that:
    - The EDGs are monitored under the MR program in accordance with 10 CFR 50.65
    - EDGs are currently designated “category (a)(2) – meeting established reliability and unavailability goals”

Example Risk-Informed Technical Specification License Amendment Request

- Outcome
  - License amendment issued
  - Safety Evaluation excerpt:
    - "The NRC staff finds that the licensee's proposed change to revise the TS to permit extending the CT from 3 days to 14 days for an inoperable EDG is acceptable because the five key principles of risk-informed decisionmaking identified in RG 1.174 and RG 1.177 have been satisfied."

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Extended Power Uprate (EPU)

- Not a "Risk-Informed" application
  - But uses risk information and insights
- Many licensees have implemented EPUs

Use of Risk Information for Non Risk Informed Applications

- The use of risk information is clear when the licensee or the NRC designates the submittal as a "risk-informed" license application

- Guidance provided in Appendix D of Chapter 19.2 of the Standard Review Plan (SRP) as to the "special circumstances" under which a detailed risk review may be necessary, even for license applications that are not designated as being risk-informed

Special Circumstances

- "Conditions or situations that would raise questions about whether there is adequate protection and that could rebut the normal presumption of adequate protection from compliance with existing requirements. In such situations, undue risk may exist even when all regulatory requirements are satisfied."

Power Uprates

- Recognized potential risk increases due to:
  - Increased heat loads at higher powers
  - Reductions in the times available to perform specific accident response actions
  - Potential impacts on the equipment loads
  - Potential increase in the frequency of reactor scrams
- Small power uprates risk increases are expected to be exceedingly small.
- Extended power uprates, notwithstanding any plant modifications to reduce risk, can increase risk
  - Potential significant impact if affects initiating event frequencies, component reliabilities, system success criteria, and/or operator response times and might involve changes for which the synergistic or cumulative effects could significantly impact risk."

Review Standard RS-001

Provides guidance for staff review
of Extended Power Uprates

Risk Review Guidance - Matrix 13
BWR Sample Safety Evaluation – Insert 13
PWR Sample Safety Evaluation – Insert 13

Builds off Regulatory Guidance 1.174 guidance
and Regulatory Issue Summary 2001-02

Risk Evaluation Purpose

- Verify that Risks Associated with Proposed EPU are Acceptable
- Determine if “Special Circumstances” are Created

Risk Evaluation Scope

- Internal Events
  - Initiating Event Frequencies
  - Component Reliability
  - Success Criteria
  - Operator Actions (HEPs)
- External Events
  - Seismic Events
  - Fires
  - High Winds, Floods, and Other Events
- Shutdown Operations
- PRA Quality

Summary

- To date no EPU application has been identified as creating "Special Circumstances"
- Most significant area impacted is typically the timing for operator actions and is typically inversely proportional to the power increase for the uprate
- Many applications use the risk insights to propose plant modifications that result in reductions in overall risk

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License Renewal Severe Accident Mitigation Alternatives (SAMAs)

- Not a "Risk-Informed" application
  - But uses risk information and insights
- Many licensees have implemented License Renewal

Quick terminology note

- Applicant for Initial License
  - SAMDA = severe accident mitigation design alternative
- Operating Reactor seeking License Renewal
  - SAMA = severe accident mitigation alternative

- SAMDA/SAMA = A feature or action that would prevent or mitigate the consequences of a severe accident
  - Hardware modifications, procedure changes, and training program improvements
  - Prevention and mitigation
  - Both internal and external events
- Although risk models and insights play a key role, a SAMA evaluation is not a risk-informed licensing action
  - It is part of the Environmental review required by NEPA

Historical context and regulatory basis

- 1980 severe accident interim policy statement
  - Identify additional cases where additional features would prevent/mitigate severe accident consequences
- 1985 severe accident policy statement
  - No present basis for generic rulemaking or other regulatory changes due to severe accident risk
  - Nevertheless, perform analysis to discover instances of vulnerability to core melt or unusually poor containment performance

Historical context and regulatory basis (2)

- 1989 court decision
  - SAMDA required for plant operation
- NRC gained SAMA experience through:
  - SAMDA evaluations for Limerick, Comanche Peak and Watts Bar
  - Containment performance improvement program
  - Individual plant examinations (IPEs) and Individual plant examinations: external events (IPEEEs)
  - Implementation of severe accident management programs (US industry initiative)

Major steps in a SAMA evaluation

1. Leading contributors to risk
   - Use plant-specific risk study or equivalent
   - External events considered to the extent practicable
2. Identify candidate SAMAs
   - Identify SAMAs, including low-cost ways of achieving functional objective
   - Use of PRA importance measures to identify important basic events
   - Utilize relevant past SAMA evaluations

Major steps in a SAMA evaluation (2)

3. Risk reduction / implementation cost estimates
   - Calculate maximum attainable benefit (MAB)
   - Perform benefit assessment and cost assessment
   - Screen out SAMAs that can't be cost-beneficial
4. Potentially cost-beneficial SAMAs
   - Estimate net value of SAMA (averted costs – cost of enhancement)
   - NUREG/BR-0058 and NUREG/BR-0184

Major steps in a SAMA evaluation (3)

5. More detailed analysis for remaining SAMAs
   - More realistic evaluation of benefits
   - More detailed implementation cost development
   - Assess effects of uncertainties

- Further Guidance:
   - ESRP (NUREG-1555, Supp 1)
   - NEI-05-01, Revision A, "SAMA Analysis Guidance Document" (endorsed by NRC Interim Staff Guidance LR-ISG-2006-03)

External Events and Uncertainty

- The SAMA analysis uses a simplified approach to account for external events and analysis uncertainties
- Benefits are typically quantified using the internal events model and then multiplied by the ratio of total CDF to internal event CDF (typically a factor of about 2 but could be as high as 10) to account for external events benefit
- Impact of uncertainties on the results of the SAMA analysis are assessed through an additional multiplier. Multiplier typically based on the ratio of the 95%ile CDF to the mean or point estimate CDF (typically a factor of about 2).
  - Any SAMAs that become cost beneficial with uncertainties are included as potentially cost-beneficial SAMAs.

Current status of SAMA reviews

- Completed SAMDA evaluations for 3 sites during initial licensing in 1989-1995
- Completed SAMDA evaluations for multiple advanced light-water reactors
- Completed SAMA evaluations for > 70 units for license renewal, including:

Insights from SAMA evaluations

- Considerations:
  - CDFs from operating plants are relatively low
  - Past programs have addressed known weaknesses
  - SAMAs typically only act on one contributor, while risk is generally driven by multiple contributors
  - Implementation costs are high for design retrofits
  - Residual risk for advanced reactors is very low
- Therefore
  - It is difficult to identify additional changes that substantially reduce risk and are cost-beneficial
  - Cost-beneficial changes usually limited to procedural changes and limited hardware changes
  - Averted onsite costs are important – promote preventative SAMAs

Potentially cost-beneficial SAMAs

- Types of cost-beneficial SAMAs:
  - SAMAs related to SBO or loss of power sequences
  - SAMAs related to internal floods, fire, seismic and other external events
  - SAMAs related to protection systems
  - SAMAs related to support systems
  - SAMAs related to procedures and training

Potentially cost-beneficial SAMAs (2)

- Specific examples:
  - Procure an additional portable 480V AC station DG for backup to EDGs
  - For internal floods, install watertight doors/wall around vulnerable equipment
  - Provide an alternate/additional compressor that can be aligned to the instrument air system
  - Use firewater systems as backup for containment spray
- An extensive list of examples is provided in the associated paper

Conclusions / information availability

- PRA has been used to identify numerous cost-beneficial improvements
- PRA importance measures play a key role in this process
- Typically low cost improvements (e.g., procedure modification) are found to be more cost-beneficial

- Information related to all aspects of license renewal, including licensee submittals and Environmental Impact Statements (which include SAMA analysis) is available at:

  http://www.nrc.gov/reactors/operating/licensing/renewal.html

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The End

Questions & Answers…..