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NRC Perspective on Risk-Informed Inservice Inspection

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Overview of Presentation

- NRC policies and principles for risk-informed regulations
- Regulations and codes for risk-informed inservice inspection
- Implementation of RI-ISI and reviews/approvals of plant specific submittals

US Nuclear Regulatory Commission Policy

The use of PRA technology should be increased in all regulatory matters to the extent supported by the state-of-the art in PRA methods and data and in a manner that complements the NRC's deterministic approach and supports the NRC's traditional defense-in-depth philosophy

Objective of ISI Program and Regulatory Requirement

Objective

- **Identify degraded conditions that are precursors to pipe leaks and ruptures leading to safety concerns.**

Regulatory Requirement

- ***10 CFR 50.55a(g)***

History of Piping Inspection at U.S. Nuclear Power Plants

- Initial Philosophy - No inspections required because
  1) "nuclear quality" piping will not fail
  2) high radiation levels
- 1970s - ASME Section XI Code provides for sample inspections to maintain confidence in structural integrity
- 1980s - Augmented inspections to address service related degradation (intergranular stress corrosion cracking and flow assisted corrosion)
- 1990s - Development and implementation of risk-informed inspection to piping systems

Current Rules for Inservice Inspection of Piping

- ASME Section XI, Division 1 is the Inservice Inspection (ISI) Code for Nuclear Power Plant Piping.
- Scope of Piping covers ASME designation Class 1, 2, and 3 Piping.
- Current 10 CFR Regulation endorses 2000 edition of ASME Section XI.
- ASME BPVC publishes Code Cases which explain the intent of Code rules or provide for alternative requirements under special circumstances.

Current Rules (con't)

- ASME Section XI requirements are specified in subsections IWA through IWD.
- IWA: General Requirements
- IWB, IWC, IWD: Class 1, 2, 3 respectively
- ASME Code is revised every 3 years with addenda issued yearly.
- R.G. 1.147 lists those Section XI Code Cases that are acceptable to the NRC staff for implementation for the ISI.
- The owner is required to submit an updated ISI plan for each 10 year inspection interval.

Current Rules (con't)

- The owner is required to submit an inservice inspection Summary Report to the NRC within 90 days of the completion of the ISI conducted during each refueling outage.
- ISI programs are planned for a 10 year interval and each 10 year interval is subdivided into inspection periods of 3, 4, and 3 (cumulative = 10) years, respectively.
- Code specifies the percentage of sample examination in years of service within the 10-year interval of:
  - 3 years: 16% to 34%
  - 7 years: 50% to 67%
  - 10 years: 100%

Current Rules (con't)

- Pressure retaining welds in Class 1 piping are examined by surface and volumetric examinations.
- Welds are selected based on location (e.g., terminal ends, joints), stress level, cumulative usage factor, dissimilar welds.
- For Class 1 piping, a minimum of 25% of welds (B-J) are inspected by surface and volumetric examination.
- Initially selected welds are examined in the same sequence during successive inspection intervals.
- For Class 2 piping, a minimum of 7.5% of welds are selected for examination by surface and volumetric examination.
- For Class 3 piping, pressure retaining boundaries are examined by visual (VT-2) examination.

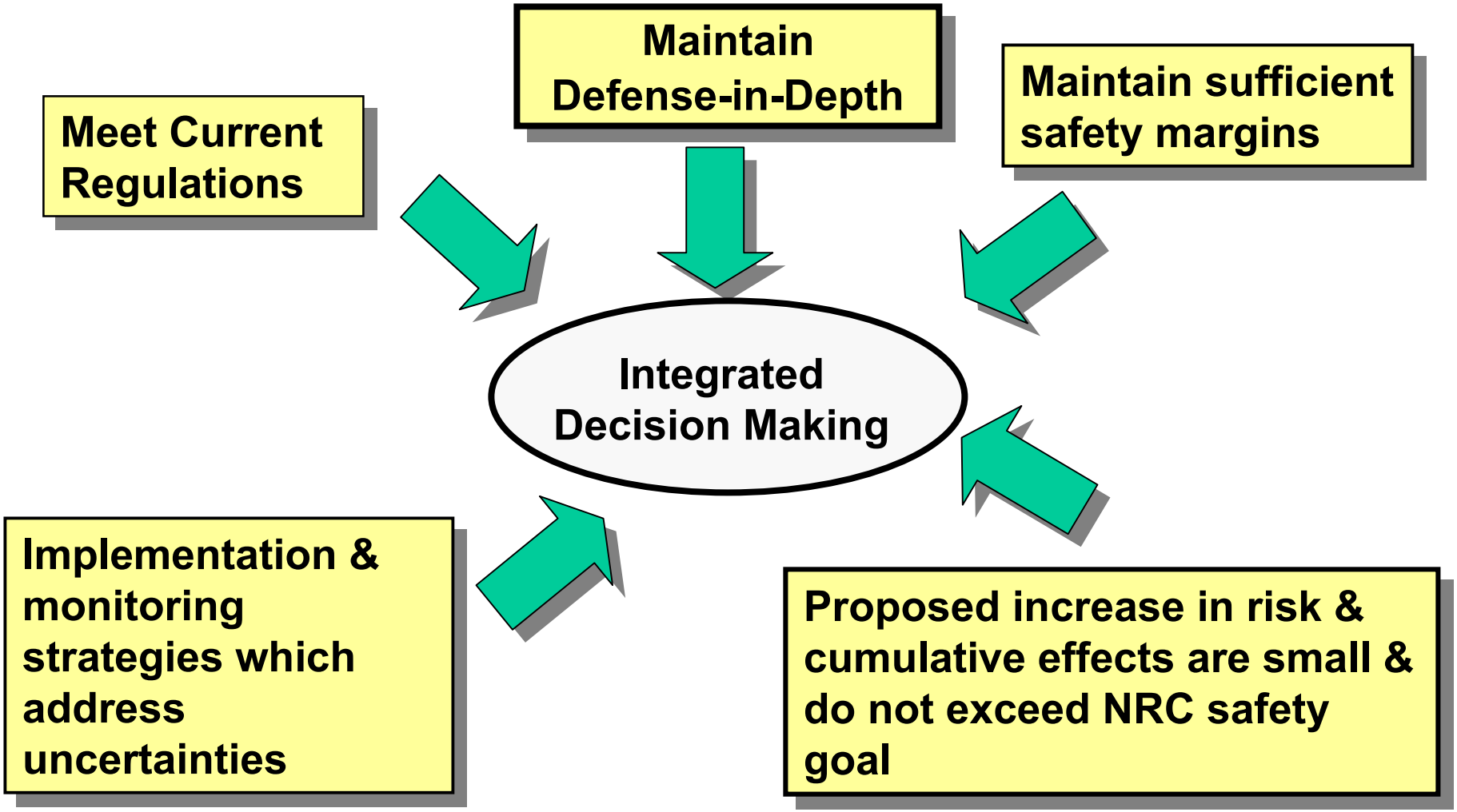
Current Rules (con't)

- If flaws are found, they are evaluated in accordance with the ASME Code requirements.
- System leakage tests (pressure tests) are conducted on Class 1, 2, and 3 piping as:
  - Class 1: Each refueling outage.
  - Class 2 & 3: Each inspection period.
- NRC can authorize alternatives under:
  - *10 CFR 50.55 a (a) (3) i:* The proposed alternative provides an acceptable level of quality and safety.
  - *10 CFR 50.55 a (a) (3) ii:* Compliance with the specified requirements would result in hardship and unusual difficulty without a compensating increase in the level of quality and safety.

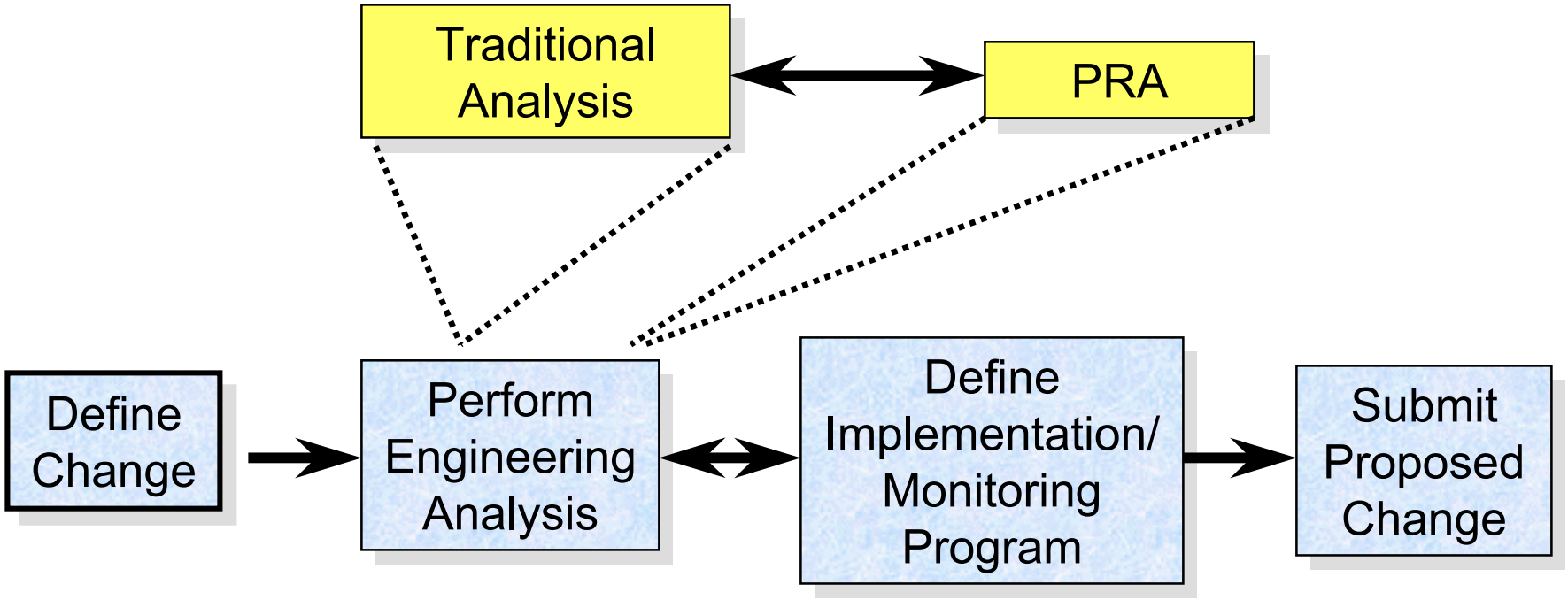
NRC Risk-Informed Regulations

- Regulatory Guides and Standard Review Plans
  - RG 1.174 General Guidance (7/98)
  - RG 1.175 IST (8/98)
  - RG 1.176 Graded QA (8/98)
  - RG 1.177 Tech Specs. (8/98)
  - RG 1.178 ISI (for Trial Use) (9/98)
- ASME - NRC PRA Standard Documents (ASME RA-S-2002)
- Code of Federal Regulations requires use of industry consensus standards

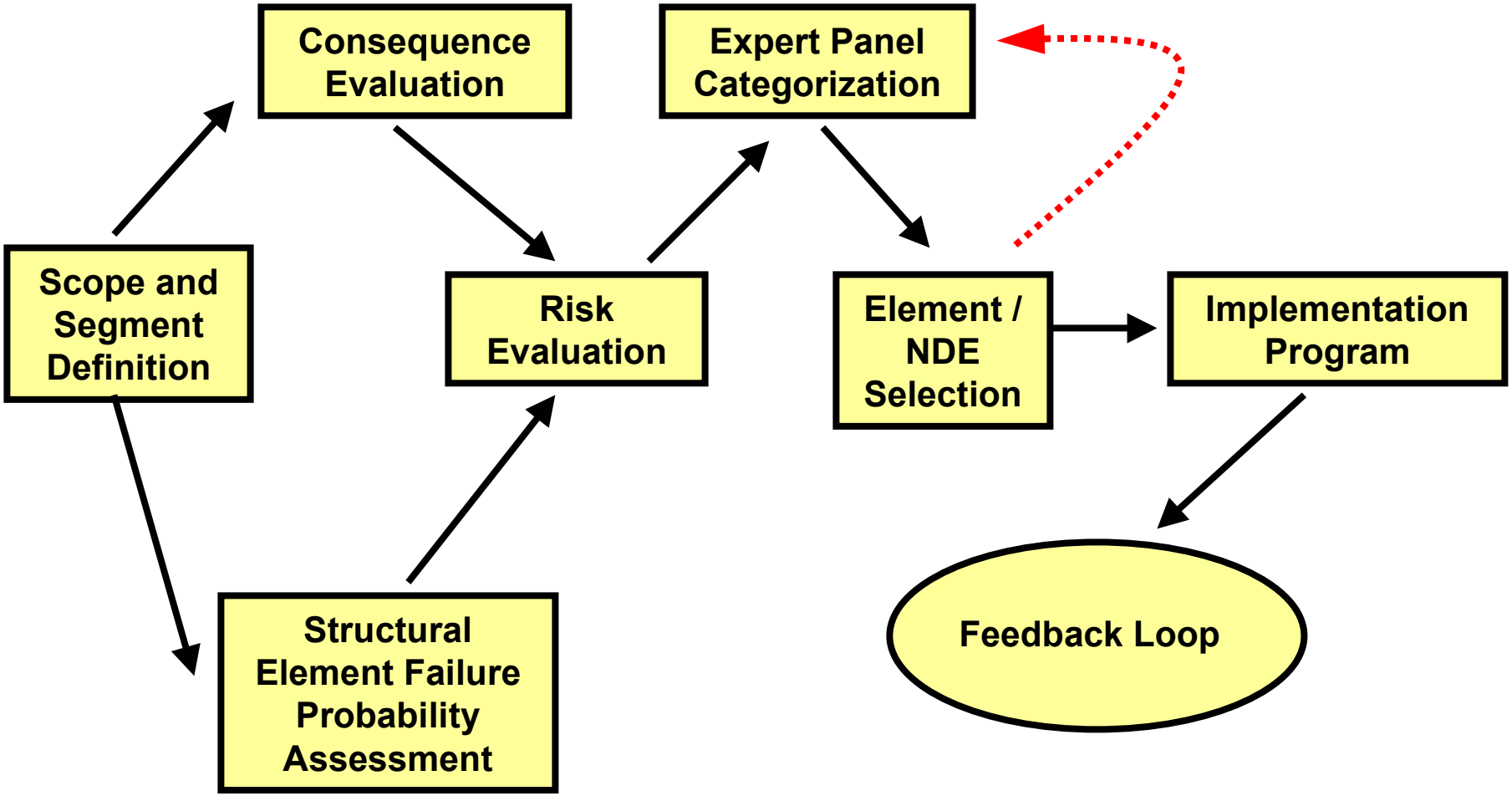
Principles of Risk-Informed Regulation



NRC Regulatory Guide Technique



Overall Risk-Based ISI Process



Scope of Current U.S. Efforts

- Limited to the selection of welds (and other locations) for inservice inspections (ASME XI)
- Changes to Section XI Inspection frequencies and NDE methods could be addressed in the future
- No change to some augmented ISI programs (IGSCC and FAC)
- No change to Section XI visual exams and system leak tests
- Full scope (all piping systems) or partial scope (e.g. reactor coolant system)
- Participation by industry, regulators, ASME code, and international organizations

Status of United States RI-ISI Activities

- RI-ISI Implementation
  - RI-ISI evaluations completed on more than 50% of US NPP's
  - 95% of US NPP's in near future
  - Methods have evolved and been optimized
  - Implementation costs have been significantly reduced
- ASME Boiler and Pressure Vessel Code
  - Section XI Working Group on Implementation of RI-ISI
  - Developing rules for NPP applications
- New Risk-Informed Applications
  - Non nuclear safety (balance of plant) systems
  - High-energy line break locations
  - Component repair and replacement rules
  - Pressure vessel and piping design
  - Inspection intervals for reactor pressure vessel beltline

Implementation of RI-ISI - NRC Role

- NRC Research supported projects at Pacific Northwest National Laboratory to develop RI-ISI methods and early pilot studies (1987-1994)
- ASME Research Task Force on Risk-Informed Inservice Inspection was supported in part by an NRC research grant (1988-1998)
- NRC staff and contractors participants in the development of Section XI code cases and pilot applications (1992-1995)
- NRC public meetings to discuss RI-ISI methodologies (1996-1998)
- Regulatory Guide 1.178 and SRP 3.9.8 for RI-ISI were issued for trial use (9/98)

Implementation of RI-ISI - NRC Role (con't)

- NRC staff reviewed and approved topical reports on methodologies of Code Cases N-577 (ASME Research/WOG) and N-578 (EPRI) (1998-1999)
- Detailed review and approval by NRC staff of early plant specific applications of code cases (1998)
- Standardized templates developed for subsequent plant specific submittals (2000)
- Audits performed as part of NRC reviews of some selected plant specific submittals (1999-present)
- Continued participation of NRC staff on ASME Section XI Working Group on Implementation of Risk-Based Inservice Inspection (1992-present)

Estimated Benefits of RI-ISI

Calculated Benefits of Industry Implementation

Number of inspections	Cost per Inspection	Inspection Savings	Dose Savings Rem	Dollars per	Total Savings
19,503	$1,000	19,503,000	4000 Rem	10,000	*59,503,000*
19,503	$3,000	58,509,000	5000 Rem	10,000	*108,509,000*
19,503	$5,000	97,515,,000	6000 Rem	10,000	*157,515,000*

Basis for Benefits

Based upon a ten year inspection interval, 4,537 inspections have been eliminated at 24 plants, which projects to 19,509 inspections eliminated at 103 plants. Project benefits for the industry are determined in the above table using various cost models.

Summary and Conclusions

- NRC policies have endorsed and supported risk-informed regulations along with the specific application to inservice inspection
- NRC has worked effectively with the ASME code and the nuclear power industry to implement RI-ISI
- The successful development and implementation of RI-ISI has been a long 10+ year process
- RI-ISI now provides more effective inspections of piping systems at a reduced burden to industry

Additional Slides

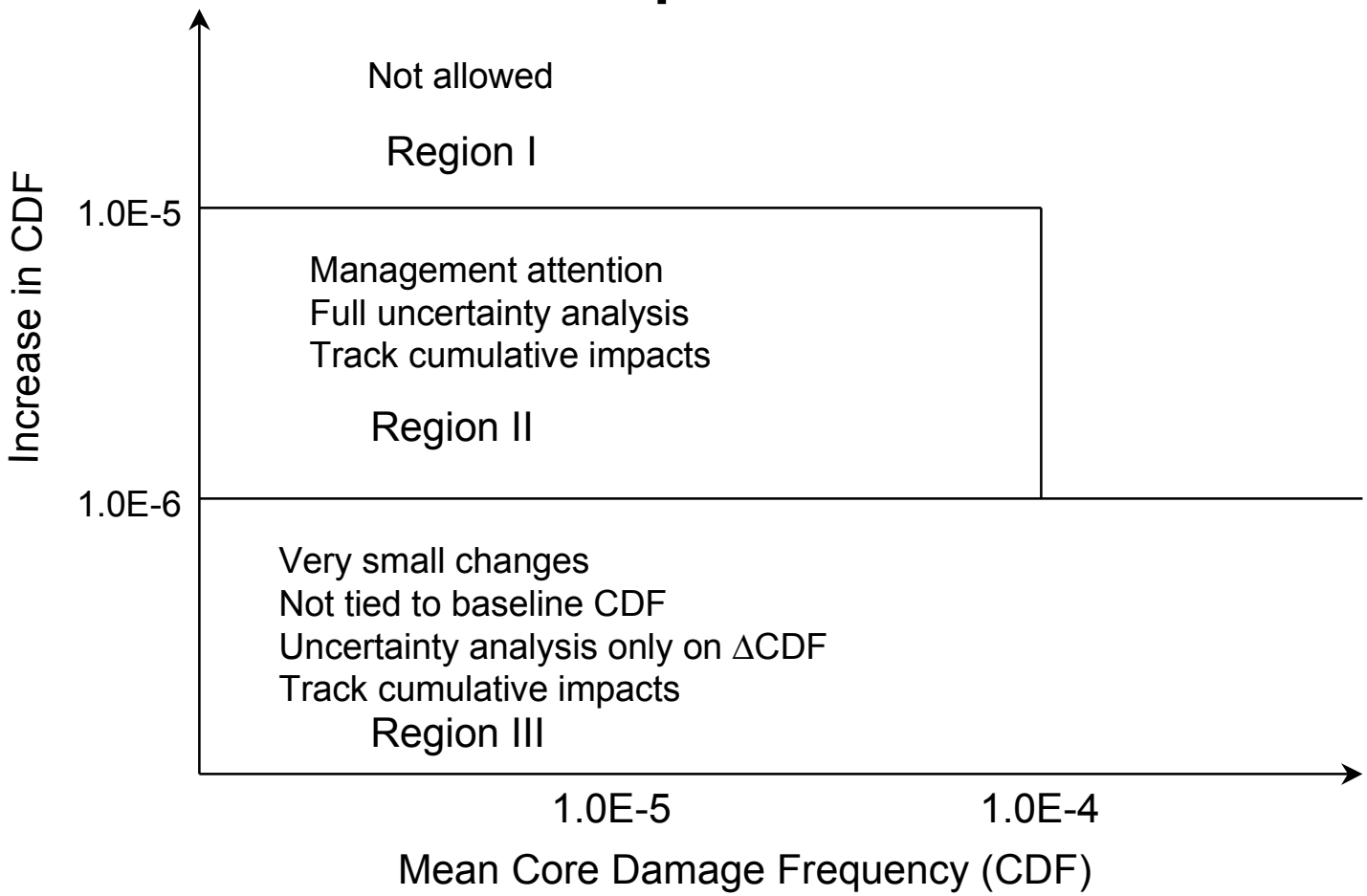
Risk-Informed ISI Pilot Plant Status

- WOG received NRC approval of Topical Report (WCAP-14572, Revision 1-NP-A) in December 1998 after extensive NRC Staff and ACRS review
- Surry (WOG pilot) received NRC approval in December 1998 for full scope program
- EPRI received NRC approval of Topical Report (TR-112657, Revision B-A) in December 1999 after extensive NRC Staff and ACRS review
- EPRI pilots-Vermont Yankee received NRC approval in Nov 1998 for limited scope program; ANO-2 received NRC approval in December 1998 for full scope program

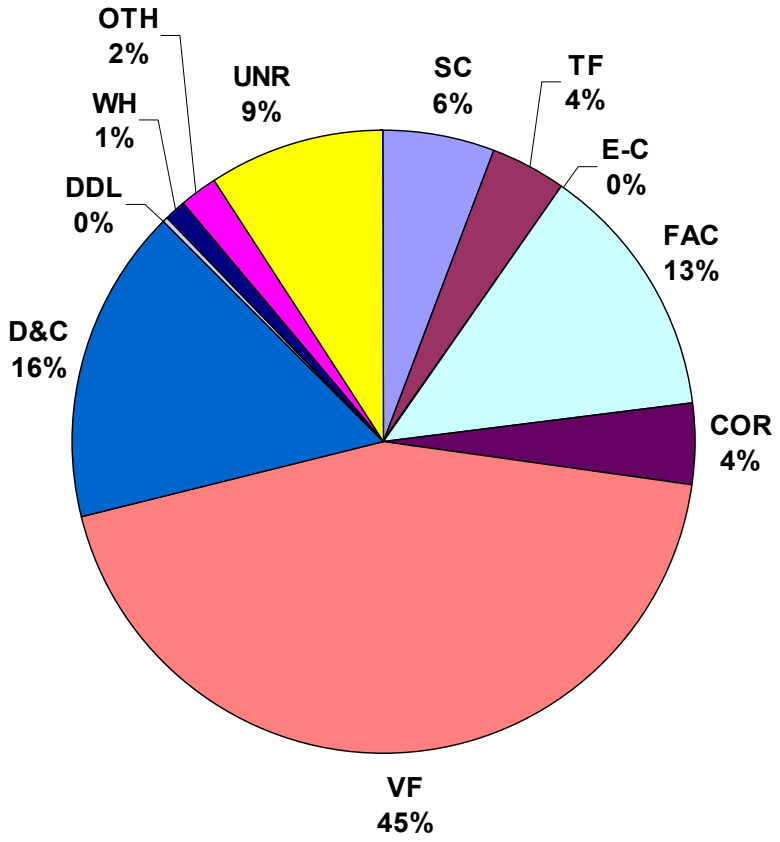
RI-ISI Technique is Modeled After Maintenance Rule

- Uses PRA
- Uses Quantitative Approach
- Plant Engineering Knowledge - Expert Judgement
- Risk Importance Measures Used - Average Contribution, Risk Reduction Worth, and Risk Achievement Worth

Mean Core Damage Frequency Acceptance Guidelines



Service Failures in Small Bore Piping (<2 inch NPS)



CF – Corrosion Fatigue

TF – Thermal Fatigue

SCC – Stress Corrosion Cracking

E-C – Erosion and Cavitation

COR – Local Corrosion Attack

VF – Vibration Fatigue

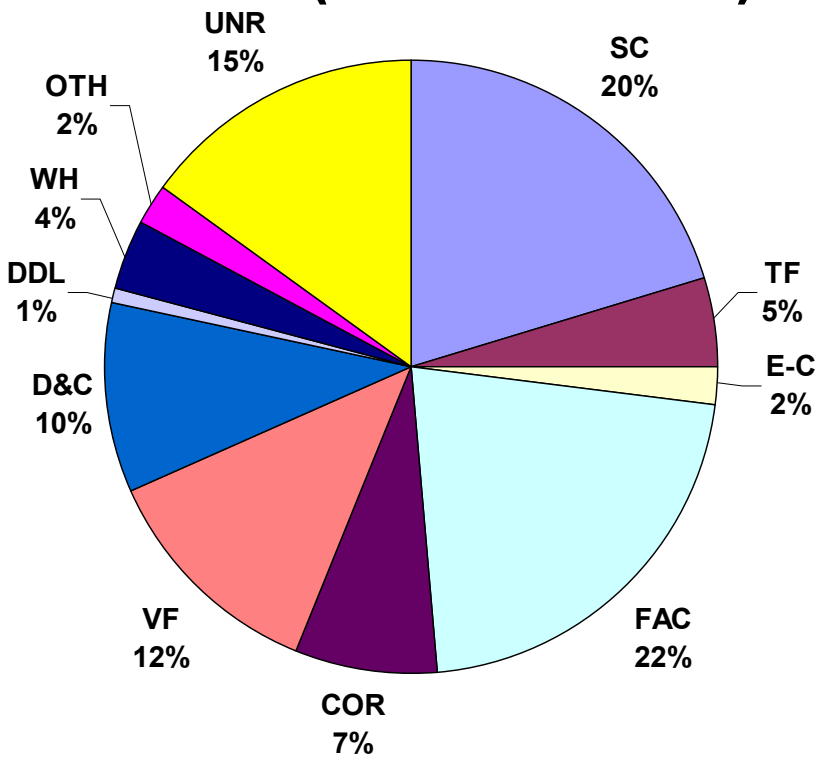
FAC – Flow Accelerated Corrosion

WH – Water Hammer

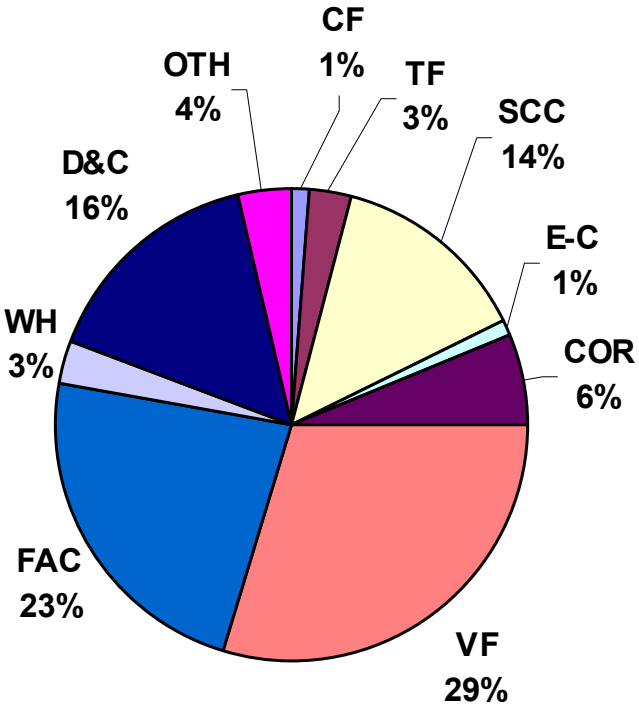
D&C – Design and Construction Errors

OTH – Other

Service Failure in Large Bore Piping (>2 inch NPS)



U.S. NPP Piping Service Failures



Estimation of Piping Failure Probability

- Data - generic and plant-specific
- Probabilistic Fracture Mechanics
- Expert Opinion

Risk-Based Inspection of Piping for U.S. Nuclear Power Plants (milestones)

- 1980's - Development of PRA methodology and the application risk-based concepts to address pressurized thermal shock of reactor pressure vessels
- 1987 to 1994 - Early studies of risk-based ranking by NRC Research performed at Pacific Northwest National Laboratory
- November 1988 - Formation of ASME Research Task Force on Risk-Based Inspection - Chaired by Ken Balkey (Westinghouse Electric)
- August 1992 - ASME Section XI Task Group on Implementation of Risk-Based Inspection
- 1994-98 - Electric Power Research Institute Research Program on Simplified Approach to Risk-Based Inspection
- 1995 - ASME Section XI approves Code Case for trial applications of RBI
- 1996-1998 - NRC Staff Develops Regulatory Guides on Risk-Informed Methods
- 1998 - Westinghouse Owners Group completes pilot application of RBI to Surry - Unit 1 nuclear power plant
- 1998-99 - NRC approves topical reports on WOG and EPRI methodologies
- September 1998 - NRC approves Vermont Yankee submittal for RBI (Class 1 piping)
- December 1998 - NRC approves Surry-1 submittal for RBI