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# Inservice Inspection Programs

## *An Historical Review and Future Directions*

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Presented at:

PVP2009
2009 ASME Pressure Vessel and Piping Division Conference
Prague, Czech Republic

July 31, 2009

# Overview

- The Early Years
  - guidelines based on fossil plant experience
- The Need for Changes
  - many initial assumptions used to establish the ISI rules and requirements were incorrect
- New Directions
  - the application of Risk Informed methodologies to focus ISI activities

# The Early Years

## *The Basis for ISI Requirements*

- Initial rules and regulations for nuclear plant inspections based on fossil plant experience
- Little consistency in original ISI programs
- AEC study (in the late 1960's) set the basis for ISI program requirements
  - Inspection of important systems and components
  - 10 years to complete all inspections
  - Random-failure philosophy
  - Preservice exams
  - Initially no guidance provided on what to do when indications were found

# The Early Years

## *Inspection Requirements*

- ASME Section XI Inservice Inspection Programs mandated by US Federal Regulation 10 CFR 50.55a
  - Class 1, 2, & 3 components
  - Rules may be used on non-Code components
- ASME Code requires inspection of
  - 100% of B-F Class 1 welds
  - 25% of B-J Class 1 welds
  - 7 ½% of Class 2 welds

# The Early Years

## *The Random-Failure Philosophy*

- Operational experience showed service-induced failures were not due to
  - random causes
  - at random times
  - at random locations
- Failures were from high stresses, fatigue, incorrect materials, and operational errors
- Many could have been predicted with proper analysis or material selection criteria

# The Early Years

## *Changes to Initial ISI Requirements*

- Initial Section XI Code was revised to
  - Target high stress areas
  - Address high cumulative usage factors (fatigue)
  - Incorporate requirements for
    - UT criteria
    - flaw acceptance standards
    - fracture mechanics analysis
    - repair and replacement rules
    - other piping & components in Class 2 & 3 systems
- Current ISI requirements set in 1978

# The Early Years

## *Changes to Initial ISI Requirements*

- Welds now selected based on “high stress/high fatigue” locations
- These revised ISI requirements were significant changes from those originally envisioned
- Augmented Inspection Programs developed to address specific degradation issues
  - Intergranular Stress Corrosion Cracking (IGSCC)
  - Flow Accelerated Corrosion (FAC)
  - Microbiologically Induced Corrosion (MIC)

# Need for Change

## *Lack of Effectiveness of ISI Programs*

- Data began to show that inspections often focused on the wrong SSCs
- The appropriate locations were not being inspected
- The correct type of exams were not being performed
- For example:
  - only 0.6% of welds inspected following ASME Section XI procedures contained flaws
  - almost all flaws detected by IGSCC Augmented Program (IGSCC)

# Need for Change

## *What Were the Plants Telling Us?*

- Inservice failures (cracks, leaks, or breaks) were found to be caused by
  - Flow Sensitive Attack (FAC, Erosion/Cavitation)
  - Stress Corrosion Cracking (IGSCC, TGSCC, PWSCC, ECSCC)
  - Vibration Fatigue
  - Localized Corrosion (MIC, Pitting, Crevice Corrosion)
  - Thermal Fatigue (Thermal Transient, TASCS)

# New Directions

## *Basis for RI-ISI Programs*

- Risk Informed ISI (RI-ISI) methodologies were developed to focus inspections on the most risk significant areas

- Key actions leading to current RI-ISI programs

- WASH-1400 (1975) – *a major step in risk quantification*
- Three Mile Island accident (1979) – *a catalyst for required use of risk analysis and risk insights*
- ASME Research Committee on Risk Technology (1988) – *developed initial RI-ISI methodology*

# New Directions

## *Approval to Risk-Inform ISI Programs*

- ASME Section XI approved 3 key RI-ISI Code Cases
  - N-560 – Alternative exam requirements for Class 1 B-J Piping Welds
  - N-577 – Westinghouse (WOG) RI-ISI Methodology
  - N-578 – EPRI RI-ISI Methodology
- WOG & EPRI prepared Topical Reports
- NRC did not endorse ASME Code Cases
- NRC did endorse the Topical Reports – *thus allowing plants to obtain approval to risk-inform their ISI program*

# RI-ISI Lessons

- > 85% US plants have implemented RI-ISI programs – many are already in the process of updating their RI-ISI program
- Examples of lessons learned
  - the use of experts
  - consistency of applications and reviews
  - effectiveness improvements

# The Use of Experts

- An essential part of the risk-informed methodology is the combination of qualitative insights and guidance with the quantitative results of probabilistic analyses
- Based on pilot plant applications and NRC guidance
  - WOG revised the expert panels to support the more quantitative nature of the WOG methodology and review all steps of the risk-informed process
  - EPRI revised the experts' role to support the simpler, process driven EPRI methodology and not be overly dependent on subjective judgments

# Consistency of Applications & Reviews
## *The Submittal Template*

- NRC & industry agreed on the need for a standard application submittal template
  - to make the RI-ISI program development and regulatory review more efficient and consistent
  - To ensure the licensees provide appropriate information in the correct format to the NRC
  - Requires information on
    - qualification to perform the analysis
    - process used to perform the analysis
    - results of the analysis – proposed changes
- The template has, & will continue, to evolve

# Effectiveness Improvements

- Non-mandatory Appendix R was developed to address NRC concerns with original RI-ISI Code Cases
  - incorporated details found in the Topical Reports.
  - items that the NRC identified as being missing in the Code Cases were included
  - concerns and questions by licensees regarding the original Code Cases were addressed

# Effectiveness Improvements

- Code Case N-716 – risk insights are used to define alternative requirements for ISI
  - builds upon lessons learned
  - establishes a generic set of requirements, such as classification and examinations to reduce RI-ISI program development effort
  - potentially eliminates many low value added exams

# Concluding Remarks

- RI-ISI methodologies have and continue to be refined as "lessons are learned"
  - Involves industry and NRC working together
  - Plant RI-ISI programs are "living programs" and also need to incorporate lessons learned
- Success of the RI ISI piping applications has lead to expansion of risk-informed methods into other areas
- Need to keep it simple while addressing basic risk-informed principles

- continued to refine and expand the use of risk-informed methodology
- major reductions in inspections, radiation exposure, and associated costs due to the implementation of the RI-ISI methodologies.
- The NRC has encouraged the appropriate use of the risk-informed approach

# Concluding Remarks

- RI-ISI
  - Provides a structured and systematic framework for allocating inspection resources in a cost-effective manner and focus inspections where failure mechanisms are likely to be present and enhanced inspections are warranted
  - Considered to be highly successful by both industry and regulator
  - Plants have realized major reductions in inspections, radiation exposure, and associated costs
  - NRC encourages RI-ISI continued refinement and application – *to allocate inspection resources in a cost-effective manner and help focus inspections where failure mechanisms are likely to be present and enhanced inspections are warranted*

# Future Directions

- NRC risk informed initiatives, including new directions for RI safety classification
  - 10 CFR 50.69, *Risk-Informed Categorization and Treatment of SSCs (Option2)*
    - Uses risk-informed safety classification to determine the applicability of special treatment requirements
    - Treatment includes quality assurance, testing, inspection, condition monitoring, assessment, evaluation, and resolution of deviations

# Piping Failures 1970-2007

# Appendix R

- Differences from original Code Cases
  - Piping exempt from examination
  - Clarification of the Duties of the Inspector
  - Applicability of pre-service examinations
  - Requirement to perform any required additional examinations during the current outage
  - An update to the 2500-1 Table requirements for examinations to reflect the experience from implementation of the Code Cases

# Basis for Risk-Informed

- All nuclear power plants were required by the NRC Generic Letter 88-20 to perform an Individual Plant Examination (Probabilistic Safety Analysis)
- Plants were to determine plant vulnerabilities to:
  - Core Damage Frequency (CDF)
  - Large Early Release Frequency (LERF)
- CDF and LERF can be used to determine an optimum inservice inspection scheme

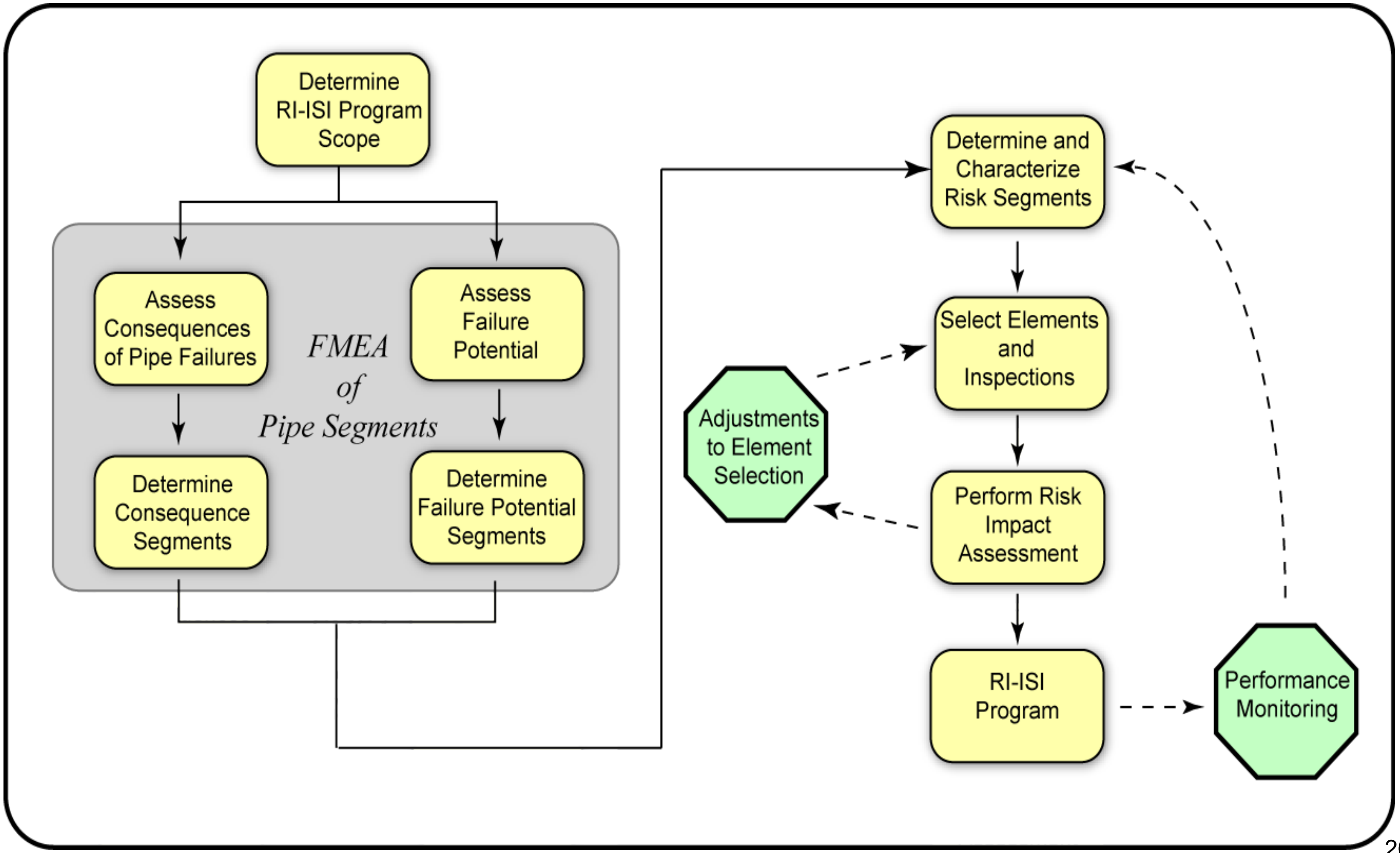
# Risk

$$\textbf{\textit{Risk = probability of event}} \times \textbf{\textit{its effects}}$$

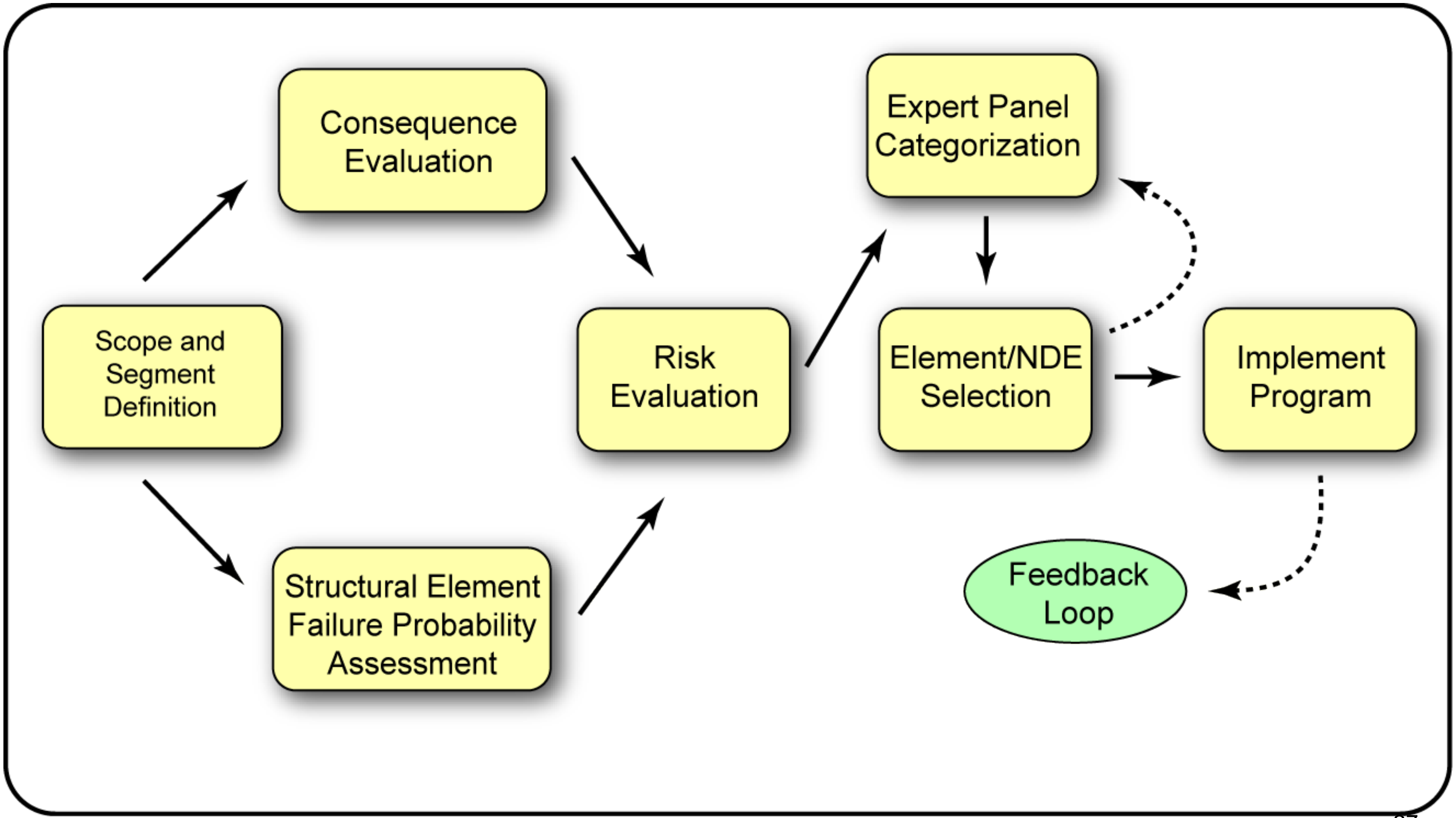
Probability of event – a function of potential degradation modes as determined by physical characteristics and operational parameters

Effects – measured by CDF and LERF

# EPRI Methodology Overview



# WOG Methodology Overview



# *The Early Years*

- SSCs were over-designed, over built, & over maintained

# Lack of Effectiveness of ISI Programs

- Section XI Task Group on ISI Optimization found
  - only 156 of 37,332 B-J welds contained flaws
  - 97% of the 156 flawed welds due to IGSCC
  - 0.6% of the welds inspected following ASME Section XI examination procedures contained flaws
  - almost all flaws detected by IGSCC Augmented Program