Proactive Strategies for Monitoring and Managing Aging Related Degradation in Highly Irradiated Reactor Internals

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Life After 60 Workshop

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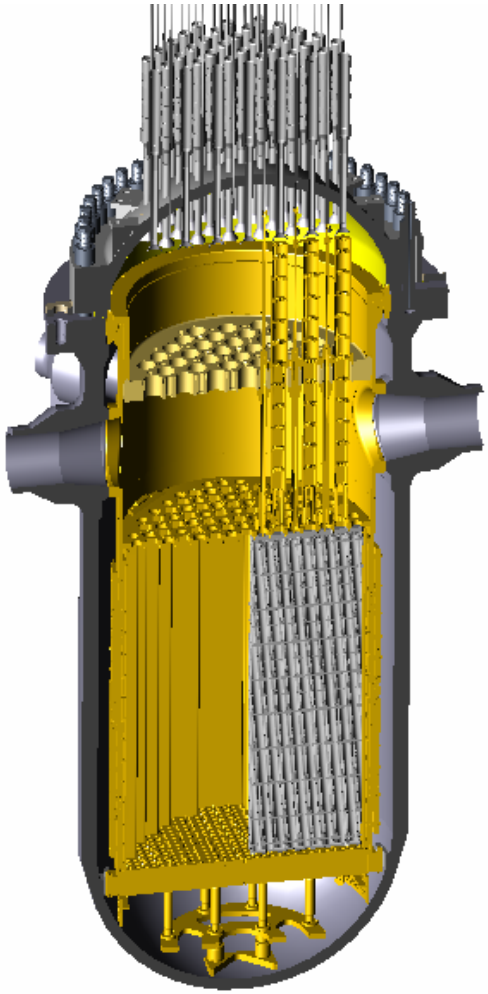
Reactor Internals

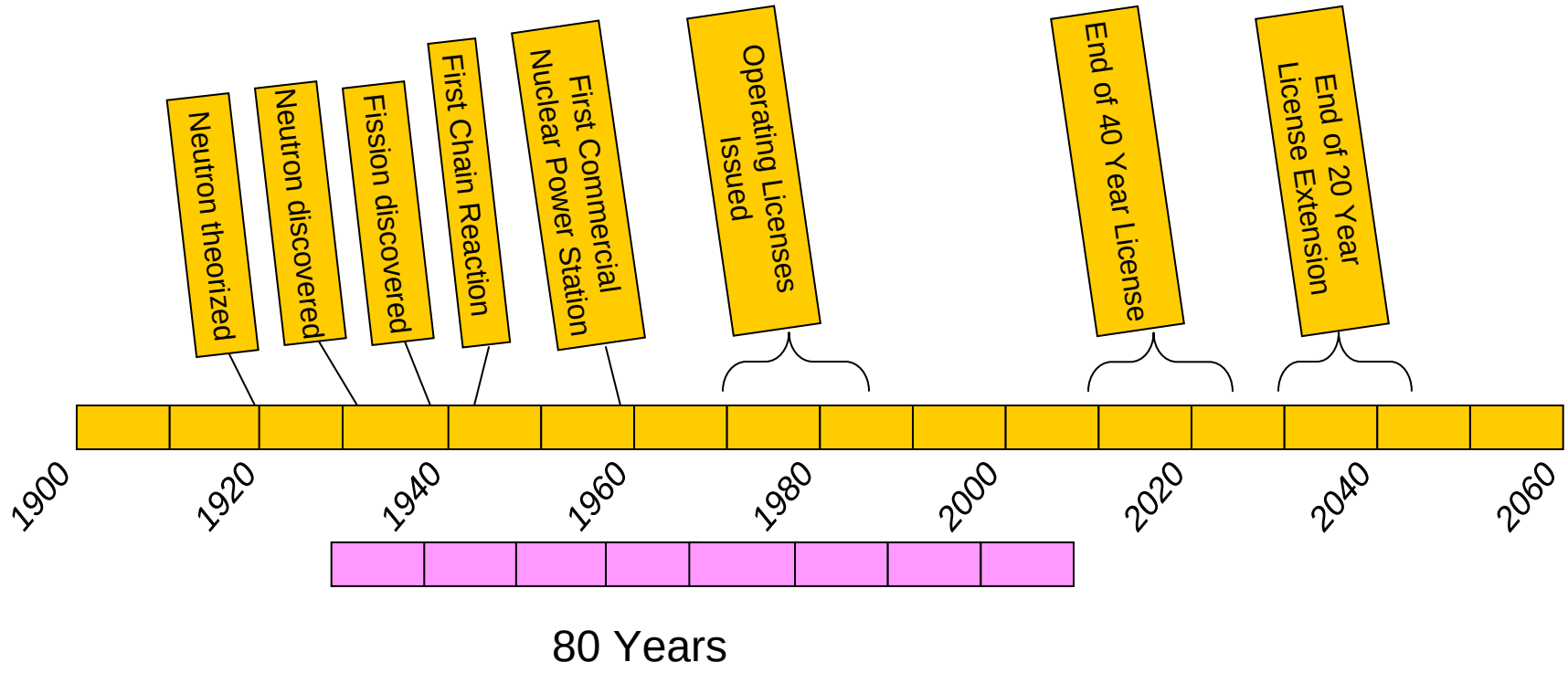


Unique Service Environment

Long Term Degradation

Require Proactive
Aging Management Program

We have limited experience with long term exposure in high radiation environments!



Unique Degradation Mechanisms

Industry Materials Reliability Program

(MEOG/MTAG/EPRI)

- Materials Degradation Matrix
  - Comprehensive catalogue of potential mechanisms
- Issue Management Table
  - Systematic analysis of current programs
  - Gap Analysis
- Reactor Internals I&E Guidelines
  - Based on Functionality Analysis
  - Recommendation for Aging Management

Materials Degradation Matrix Recognizes 17 Modes of Degradation

Applied to all reactor components.
(not just internals!)

Basis for developing the Issue Management Table!

Type	Mode	Code
Corrosion/Wear	Flow Assisted Corrosion	C/W:FAC
Corrosion/Wear	Pitting	C/W:Pitt
Corrosion/Wear	Wastage	C/W:Wstg
Corrosion/Wear	Wear	C/W:Wear
Fatigue	Environmental	Fat:Env
Fatigue	High Cycle	Fat:HC
Fatigue	Thermal	Fat:Th
Mechanical	Flux Effect	RIT:Flux
Mechanical	Irradiation Embrittlement	RIT:Emb
Mechanical	Thermal Aging	RIT:ThAg
Mechanical	Thermal Neutron	RIT:Thn
Mechanical	Void Swelling	RIT:VS
Stress Corrosion Cracking	Intergranular	SCC:IG
Stress Corrosion Cracking	Irradiation Assisted	SCC:IA
Stress Corrosion Cracking	Low Temperature Crack Propagation	SCC:LTCP
Stress Corrosion Cracking	Primary Water	SCC:PW
Stress Corrosion Cracking	Transgranular	SCC:TG

Issue Management Table

15/62 Gaps Related to Reactor Internals

Inspection Related Gaps

1 I&E Guidelines: Reactor Internals
8 NDE Accessibility: Reactor Internals
20 UT Demonstration: Baffle Bolting
32 NDE Capability: Void Swelling (Identification & Characterization)
33 NDE Capability: Baffle Former Assembly IASCC
43 NDE Capability CRGT Support Pins

Degradation Related Gaps

10 Thermal & Irradiation Embrittlement: Synergistic Effects on CASS & SS Welds
16 Fluence Impact on SCC of Stainless Steels
18 High Cycle Fatigue - Internals
23 PWSCC Management: Ni-Alloy Reactor Internals
28 Fatigue Environmental Effects: Reactor Internals
31 Assess Void Swelling & Stress Relaxation Significance: PWR Reactor Internals
35 Wear & High Cycle Fatigue: Steam Generator Tubes & Internals

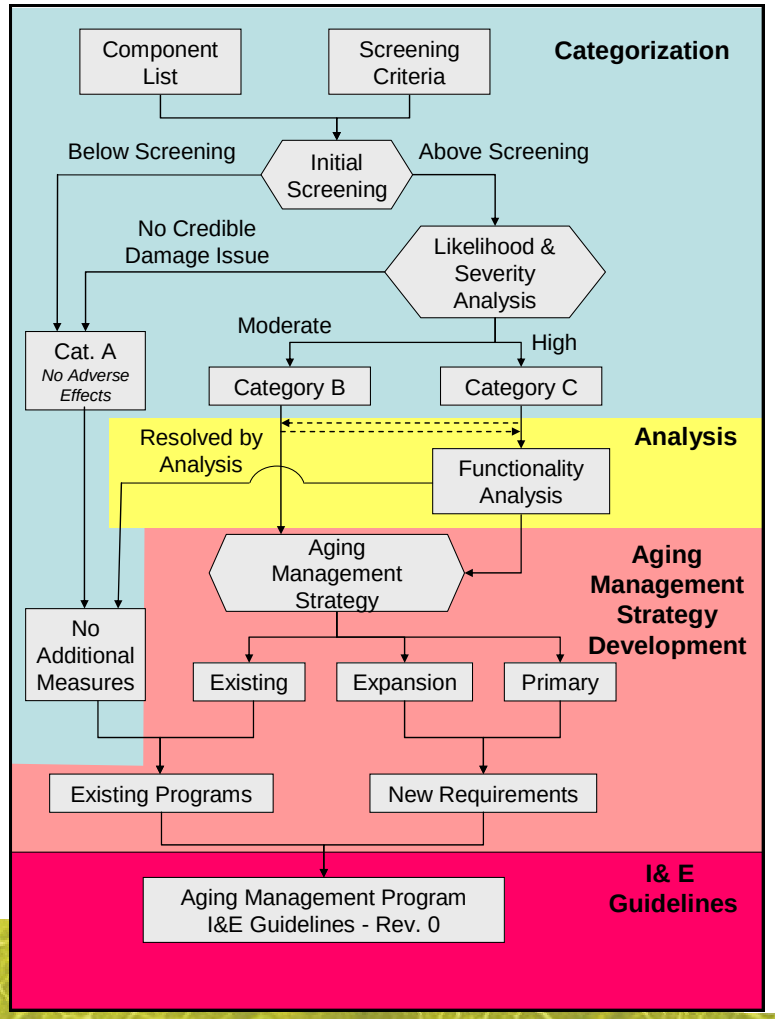
General Assessment Gaps

25 Baffle Bolting Assessment
49 Irradiation Effects: Ni Alloys (Reactor Internals)

The I&E Guidelines

- Based on Exhaustive Screening Process

- Inspection Guidelines:
  - What to inspect
  - When to inspect
- Evaluation Guidelines
  - What is acceptable
  - What do we do?
    - Mitigate
    - Repair
    - Replace



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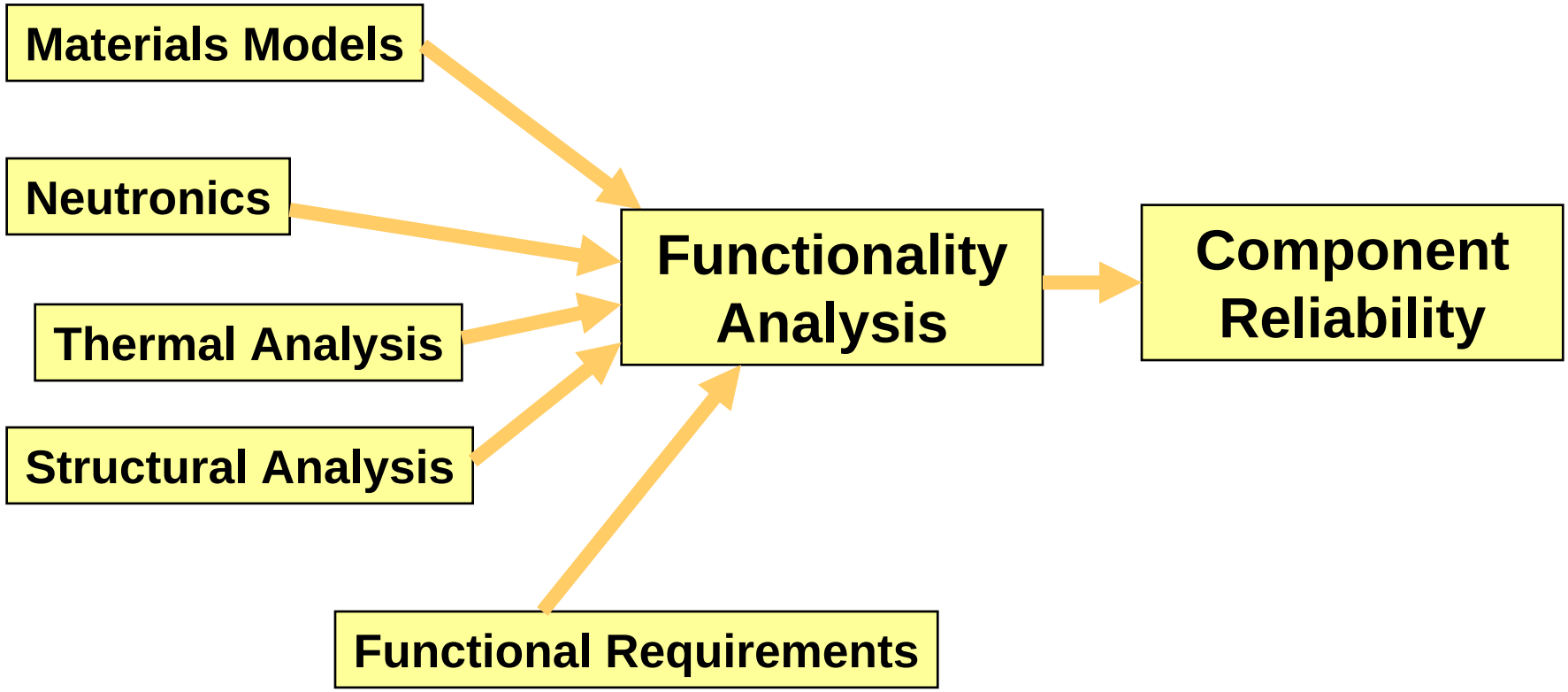
Functionality Analysis

- A Multi-Discipline Effort



The Cracking Mechanisms

- SCC (Stress & Environment)
- IASCC (Irradiation, Stress & Environment)
- Fatigue (Transient Loading, Environment?)

Produce observable cracks
Most probable in regions of stress concentration

The Embrittlement Mechanisms

- Irradiation Embrittlement (Dose & Temperature)
- Thermal Embrittlement (Time, Temperature & Composition)

Changes in material properties

- Strength (increase)
- Ductility (decrease)
- Toughness (decrease)

The Dimensional Stability Mechanisms

- Void Swelling (Temperature & Dose)
- Irradiation Induced Stress Relaxation/Creep (Dose & Stress)

Component Distortion
Modify Stress/Strain Distribution
  – Affects SCC, IASCC and Fatigue

The Wear Mechanism

- Difficult to compare or rank wear potential in identified components

Tables in Draft I&E Guidelines

Primary Components Table					
Component	**Applicability**	**Effect (Mechanisms)**	**Expansion Link (Expansion Item)**	**Examination Method**	**Examination Coverage**

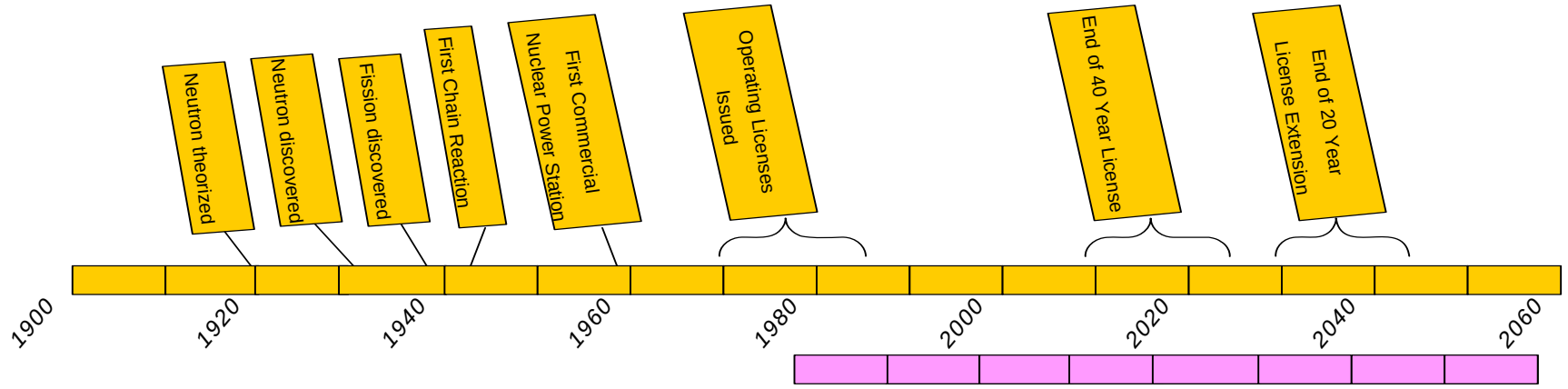
Expansion Components Table					
Component	**Applicability**	**Effect (Mechanisms)**	**Expansion Link (Primary Item)**	**Examination Method**	**Examination Coverage**

Life Beyond 60
- Is there a cliff at 60 years?

- Swelling may have a long incubation or non-linear onset.
- SCC initiation times are difficult to predict.
- ???

Life Beyond 60
- What will the future look like?

- Must plan for improved technologies.
- At 20 year extension relatively few utilities are considering replacement/upgrade.
- At 40 years beyond original license, economics of replacement/upgrade are more favorable.



80 Years is a very long time!

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