



# **Probabilistic Baffle Former Bolts Aging Management**

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# A Philosophy Check...

## ▶ Life Cycle Management INPO AP-913

- ◆ “The integration of aging management and economic planning to **optimize** the operation, maintenance, and service life of systems, structures and components; maintain an acceptable level of **performance and safety**; and **maximize return on investment** over the service life of the plant.”

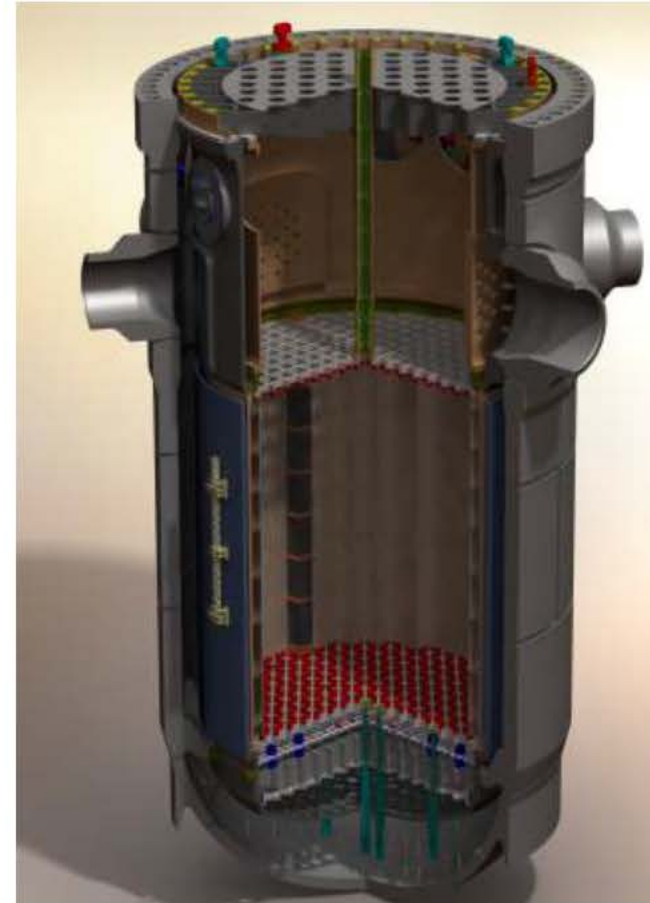
## ▶ What is successful BFB Asset Management?

- ◆ It's more than just Volumetric Exams on a given schedule
- ◆ It's more than just Replacing Bolts
- ◆ It's more than just Implementing Plant Modifications



*It's integrating these to justify safe operation  
in line with plant specific economics  
and enterprise risk management.*

# Baffle-to-Former Bolts (BFB)



***AREVA's probabilistic analysis methods have been applied to RV internals bolting***



# Drawing on SGMP Experience

## ► Topics of Interest from Steam Generator Integrity Assessment Guidelines

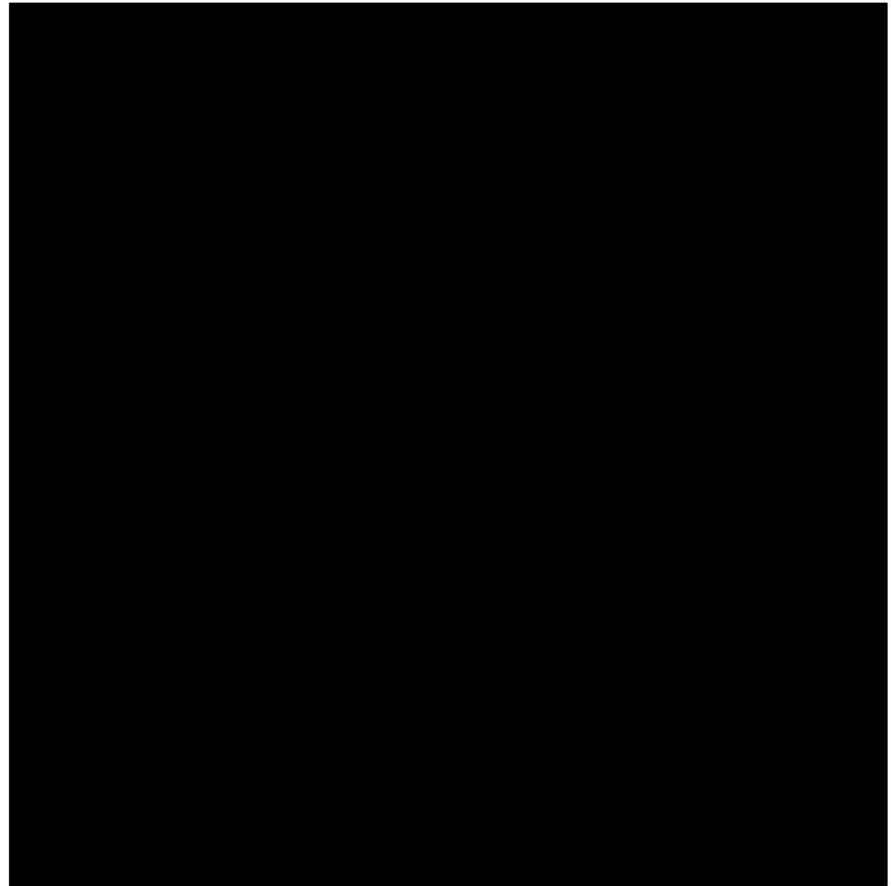
### ◆ Inspection

- Frequency
- Sample Size

### ◆ Plant Responses

- Repair
- Reduce Exam Interval

### ◆ Define Operating Interval based on future state



***Deterministic Design Basis Analyses...  
... with uncertainty statistically characterized***

# Pressing BFB Questions ... Being asked

## Re-examination Interval

“What is the risk of not meeting **my design basis**, given the degradation observed **at my plant**?”

## Initial Exam Timing

“What is the risk of not meeting **my design basis**, given the degradation observed **in the industry**?”

## Available Data?

Is sufficient information available to answer these questions?

- Future Bolt Failure Model?
- Design Basis Information?



# Probabilistic BFB Aging Management

## ► Generate “many” future states based on

### ◆ NDE Results

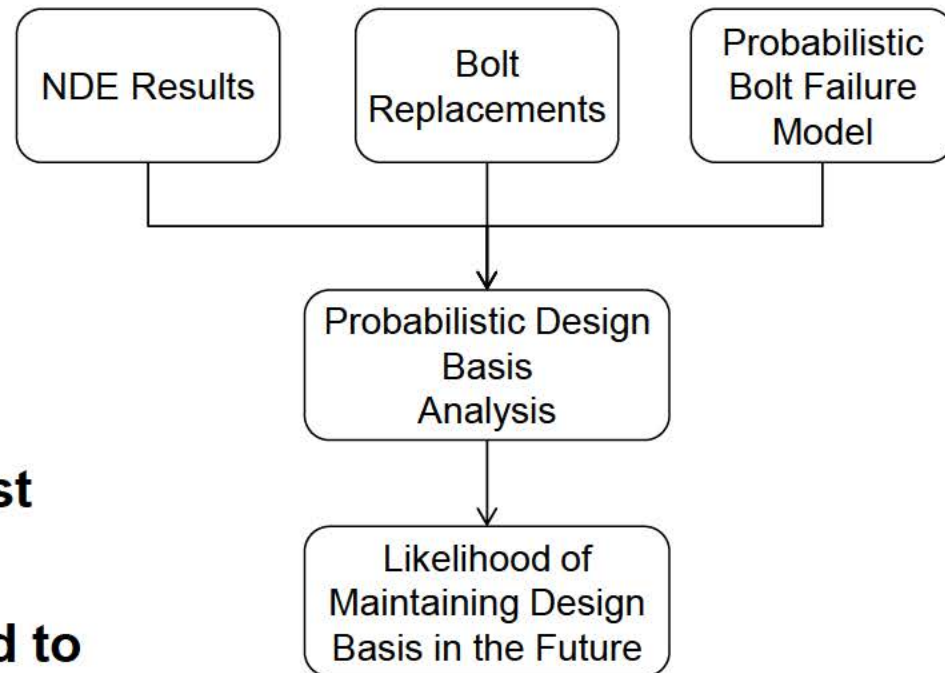
- Results from Inspected Bolts
- Probability of Detection
- Uninspected Bolts

### ◆ Bolt Replacements

### ◆ Future Bolt Failure Model

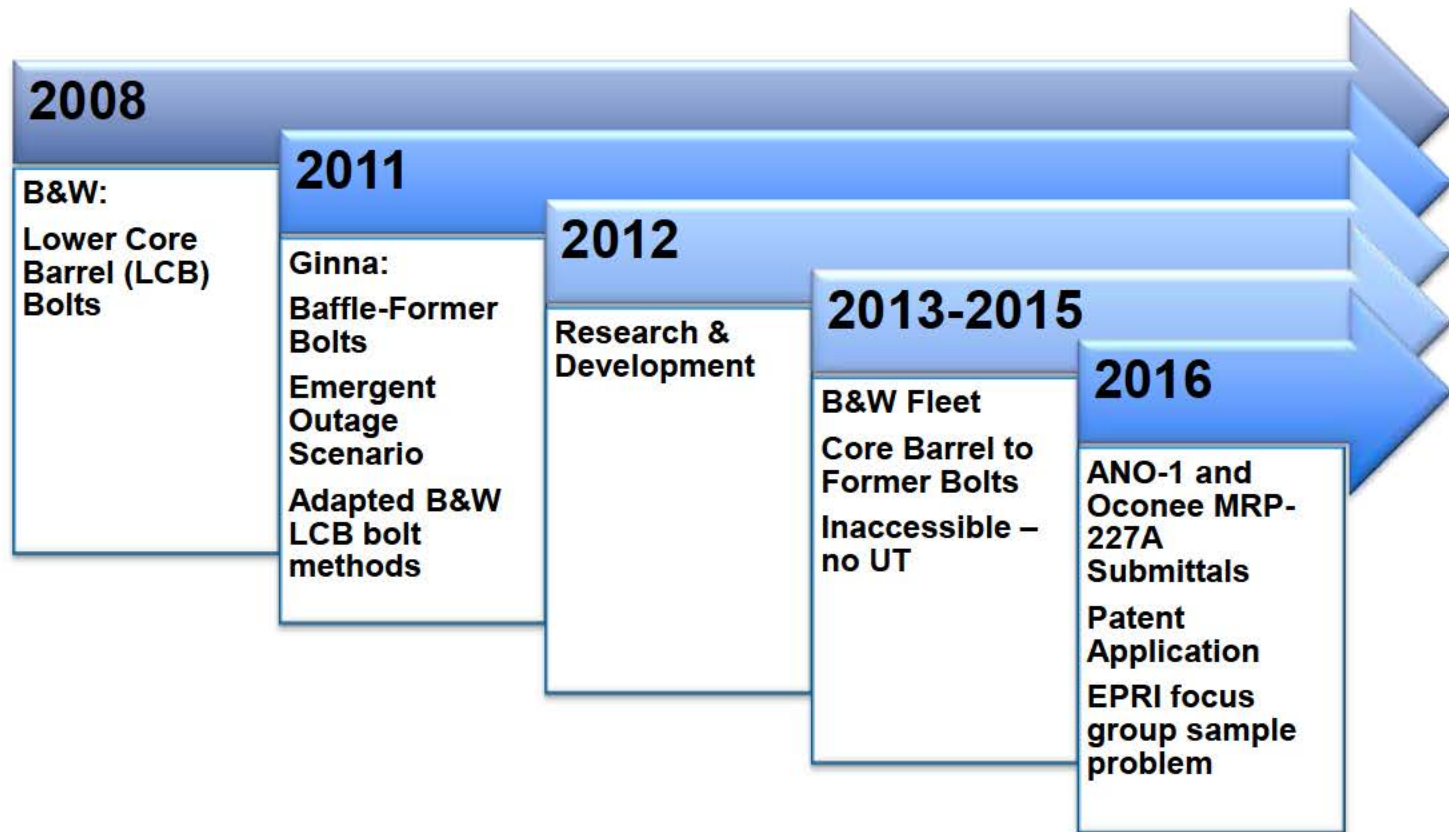
## ► Analyze each future state against design basis

## ► Re-examination interval selected to preserve design basis with xx% confidence



***Ensure Design Basis is met at End of Re-exam interval***

# Evolution of AREVA's Probabilistic Bolting Solution



***AREVA's application of probabilistic analysis methods to RV internals bolting is unique in the industry***

# Probabilistic BFB Aging Management

## ► Generate “many” future states based on

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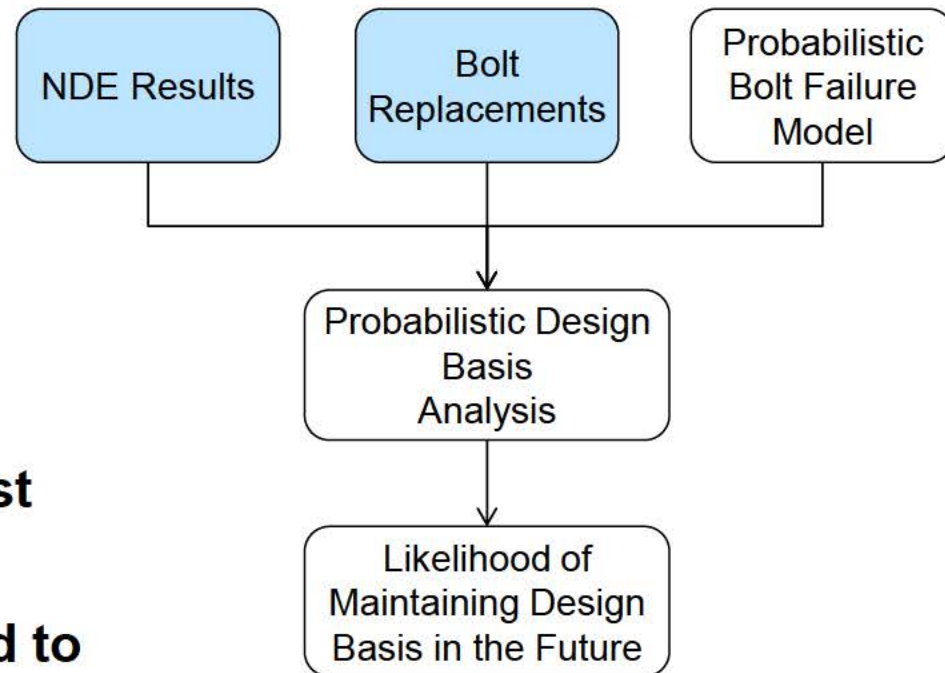
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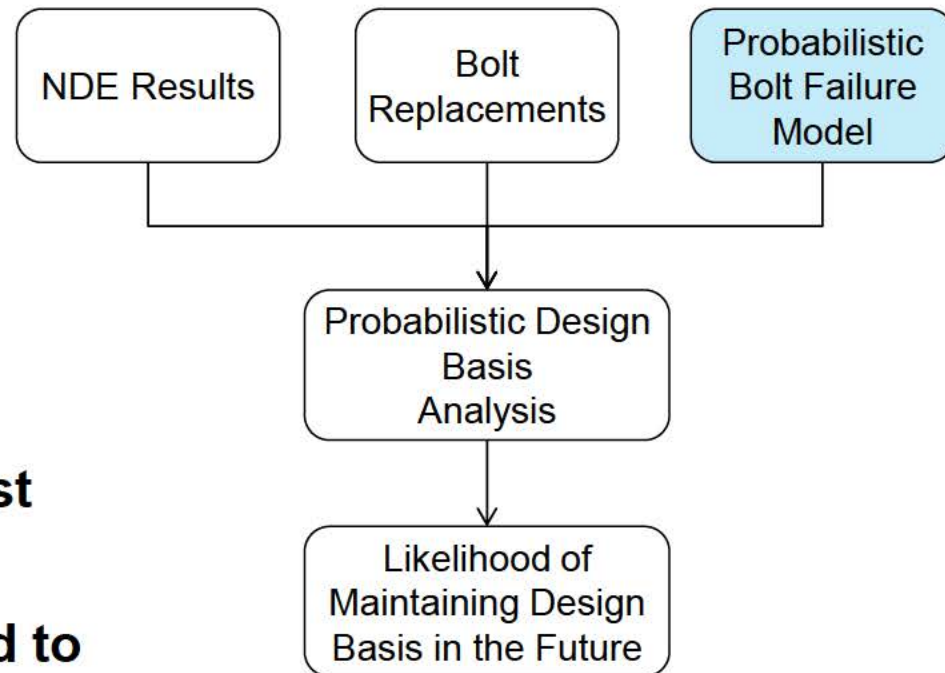
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**Ensure Design Basis is met at End of Re-exam interval**

# Empirical Model Form

## Failure Rate as Function of Time (Weibull Distribution)

- “Acceleration” Factor from Industry OE, indexed to plant specific NDE results

## Failure Rate as Function of Location (Spatial Bias Function)

- Disperses the quantity of failures throughout all BFB locations
- Distributed Function – sampled once for every simulation trial

# Probabilistic BFB Aging Management

## ► Generate “many” future states based on

### ◆ NDE Results

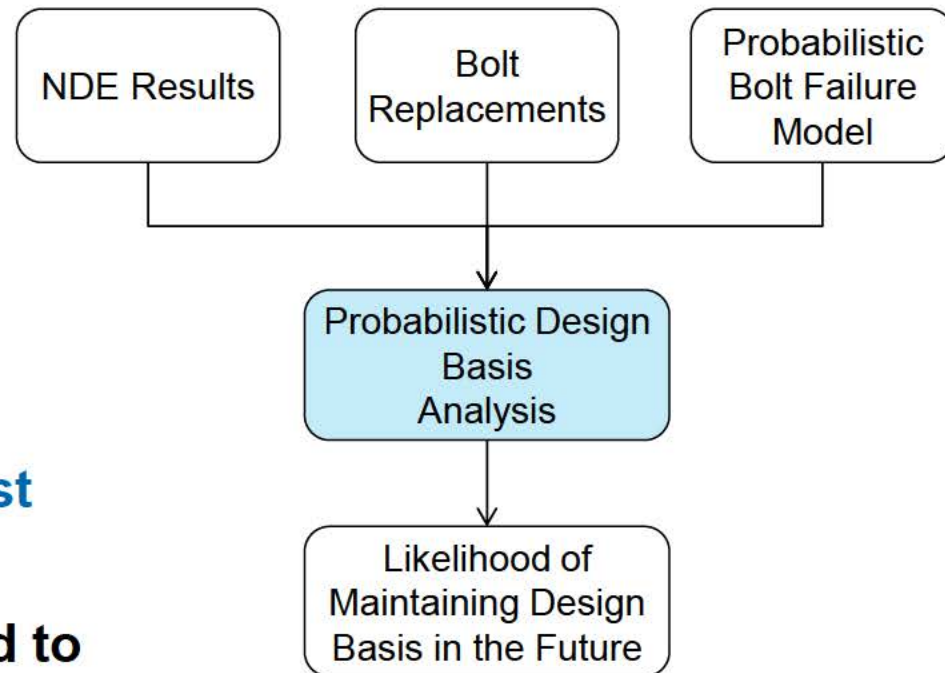
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### ◆ Bolt Replacements

### ◆ Future Bolt Failure Model

## ► Analyze each future state against design basis

## ► Re-examination interval selected to preserve design basis with xx% confidence



**Ensure Design Basis is met at End of Re-exam interval**



# Probabilistic BFB Aging Management

## ► Generate “many” future states based on

### ◆ NDE Results

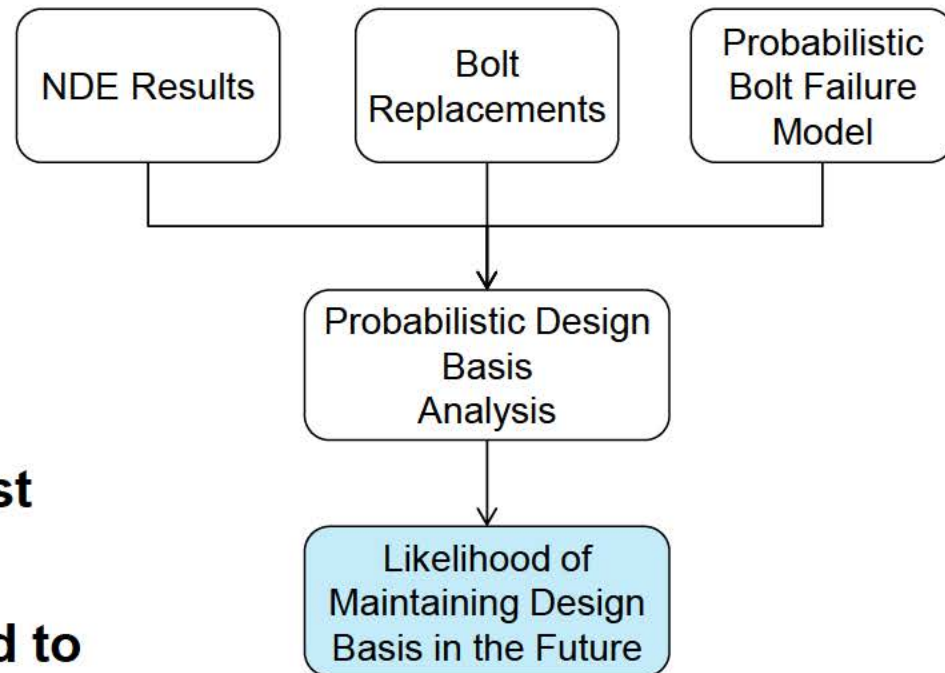
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### ◆ Bolt Replacements

### ◆ Future Bolt Failure Model

## ► Analyze each future state against design basis

## ► Re-examination interval selected to preserve design basis with 95% confidence

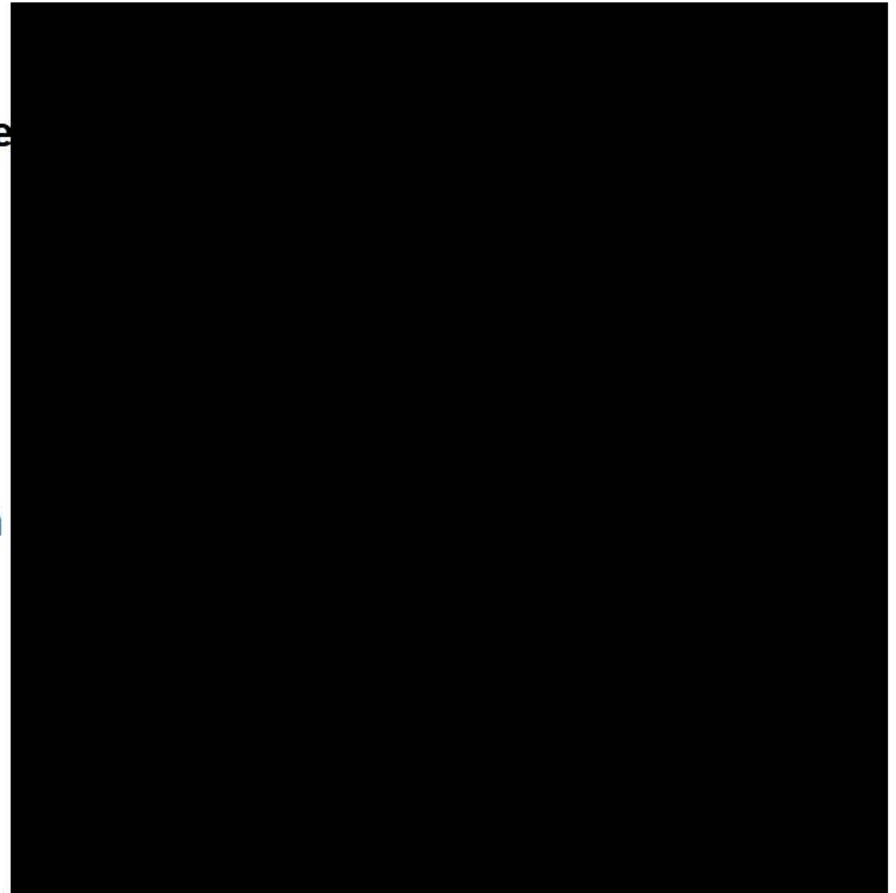


***Ensure Design Basis is met at End of Re-exam interval***



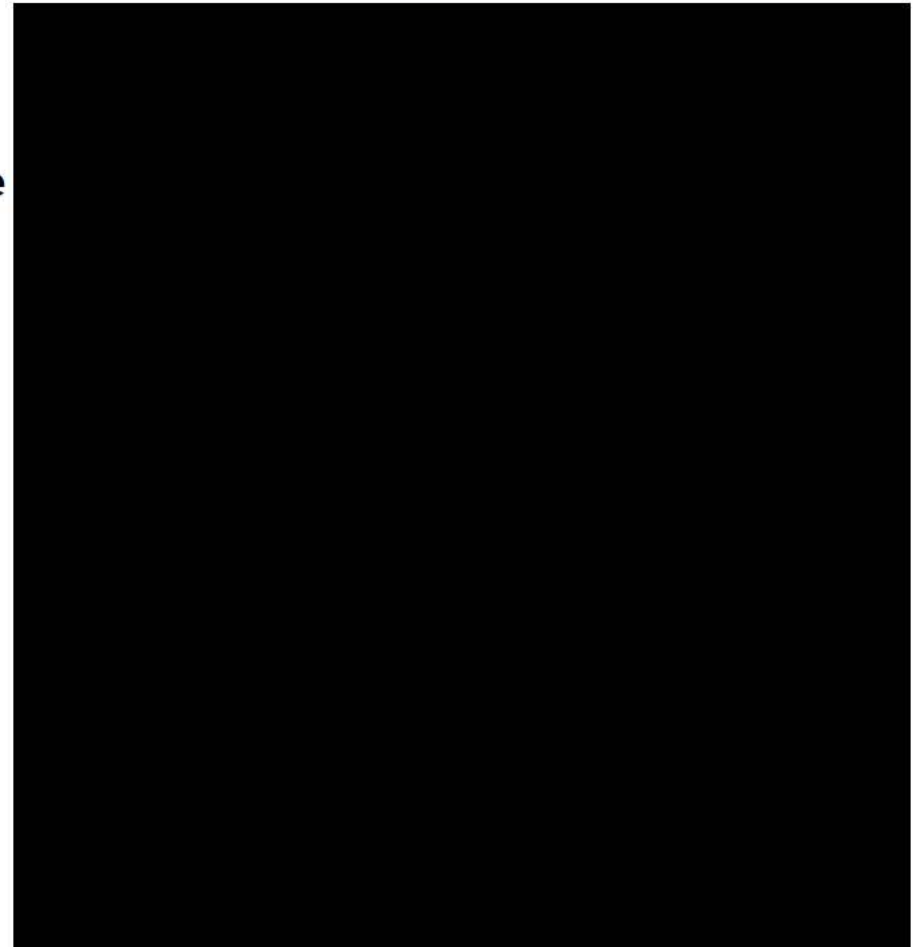
# Pattern Filtering Rules

- ▶ **Pattern Filtering Rules**
  - ◆ used to determine if future failure pattern is acceptable
  - ◆ based on bolt quantity and bolt spacing
  - ◆ Future failure pattern considers NDE results, uncertainty from POD, bolt replacements, and uncertainty in future degradation
- ▶ Rules evaluate integrity of individual structural members
  - ◆ Each plate is a unique analysis
- ▶ **Result: Probability of Acceptable Bolt Pattern**
  - ◆ based on thousands of forward looking scenarios



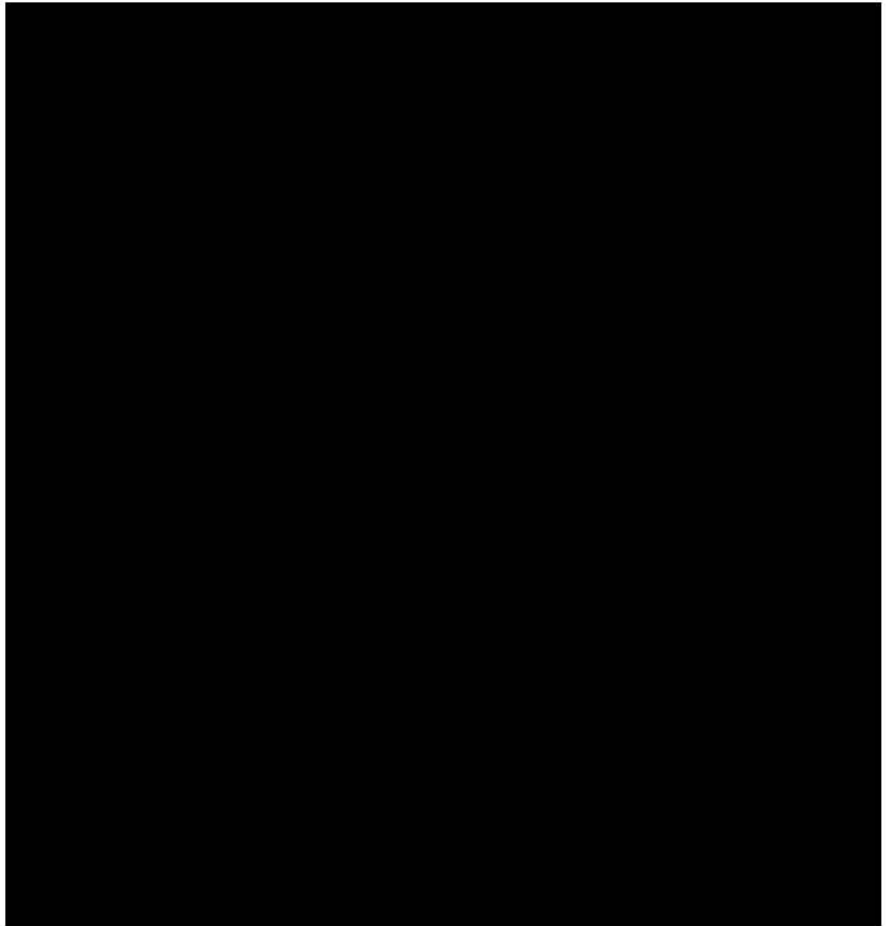
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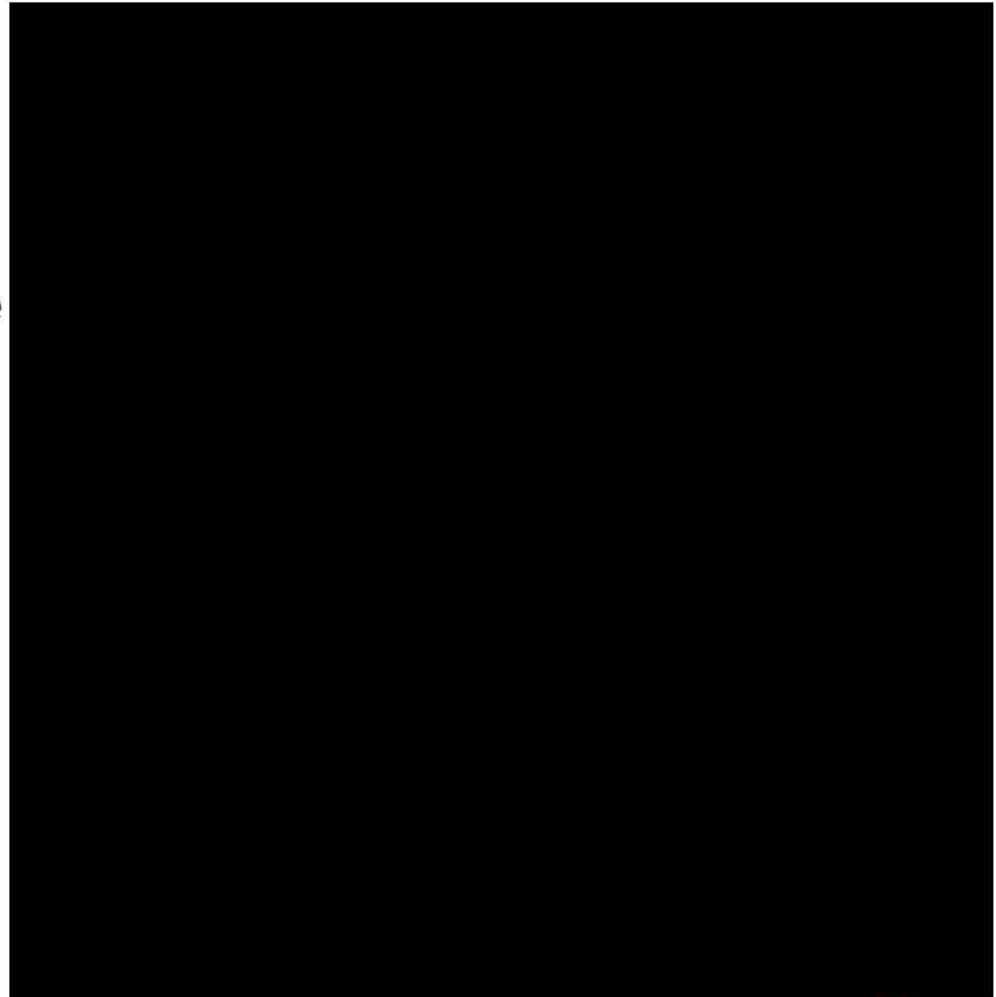
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# Integrated Analysis of Future Degradation Against Design Basis

- ▶ **Probability of Maintaining Design Basis explicitly considers**
  - ◆ **uncertainty in BFB failure rate, failure location**
  - ◆ **plant specific IASCC susceptibility factors**
  - ◆ **Plant specific initial condition**
    - POD of NDE Technique
    - NDE results
    - Bolt Replacements





# Pressing Questions ...

## Answered

### Re-examination Interval

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**AREVA's Probabilistic Solution provides the only comprehensive solution to BFB Aging Management**

