

Nuclear Power Plant O&M Optimization with Framatome Enhanced Accident Tolerant Fuel and Plant Data Analytics

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Framatome Innovation to Improve Nuclear Plant Performance and Safety

- Nuclear power plants today are facing increasing challenges in operations resulting in demands for operational flexibility including maintenance optimization, improved fuel cycle economics and higher fuel utilization.
- This presentation will present two technology developments that Framatome has delivered to utility customers.
 - Enhanced Accident Tolerant Fuel (EATF)
 - Plant assets data analytics.

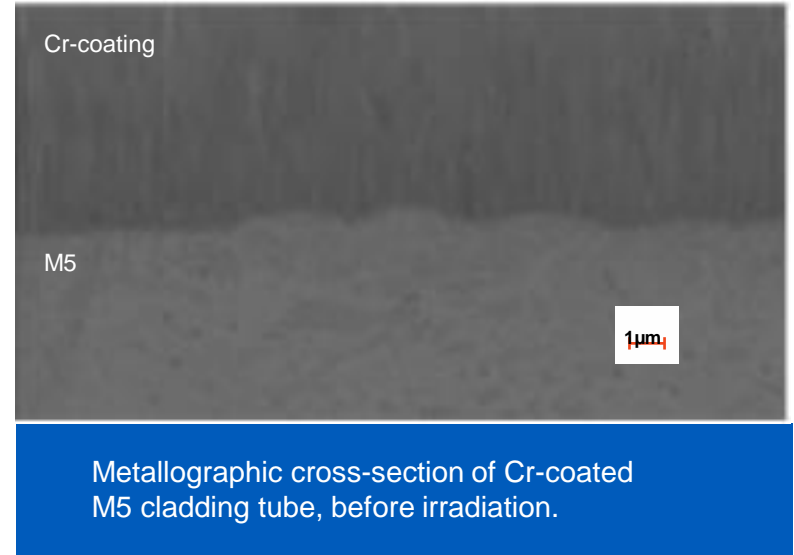
The EATF Challenge

- Following the Fukushima accident in 2011, the nuclear industry was challenged to research, develop and design nuclear fuel products that would provide improved safety margins in accident scenarios.
- Framatome has focused on researching and developing comprehensive near and long term solutions under the PROtect program.
- Our near-term solution is based on two (2) primary close-to-market technologies: Chromium-coated fuel rods and Cr₂O₃-doped fuel pellets.



Chromium-Coated Cladding

- **Chromium-coated cladding demonstrates significant safety margin gains**
 - Improves high-temperature oxidation resistance and reduces hydrogen generation during loss of cooling accidents.
 - The coating serves to prevent hydrogen diffusion into the M5 alloy, preventing the loss of ductility, and ultimately improving the fuel's ability to maintain a coolable geometry.
 - Cr-coating significantly improves wear resistance of cladding in contact with grids or debris.



Cr2O3-doped Fuel

- Cr2O3-doped fuel is characterized by large grain size and improved viscoplasticity. We have in-pile experience of Cr2O3-doped fuel since 1997 with a burn-up of up to 75 MWd/kgU
 - Larger grain size serve to trap fission products in the fuel to reduce amount of release
 - Fuel pellet has more flexibility, which mitigates cracking due to temperature transients

PROtect also improves fuel cycle economics during normal operation.



Long-Term Solutions

- **Silicon carbide-based cladding: Offer more margin gain under Beyond Design Basic Accident scenarios using a silicon carbide-based cladding solution**

- Very low oxidation kinetics under high-temperature steam in light water reactor conditions
- High strength at high temperatures
- High melting temperature



Codes & Methods

- Our current Codes and Methods have been revised for Cr₂O₃-doped fuel in reloads and for Cr-coating in lead fuel assemblies worldwide.
- A Topical Report supporting Cr₂O₃ doped BWR UO₂ fuel was approved by the US NRC and the final SER has been received, which enables the use of Cr₂O₃ doped fuel for BWRs in the US.

Safely bringing enhanced value
by Advanced C&M



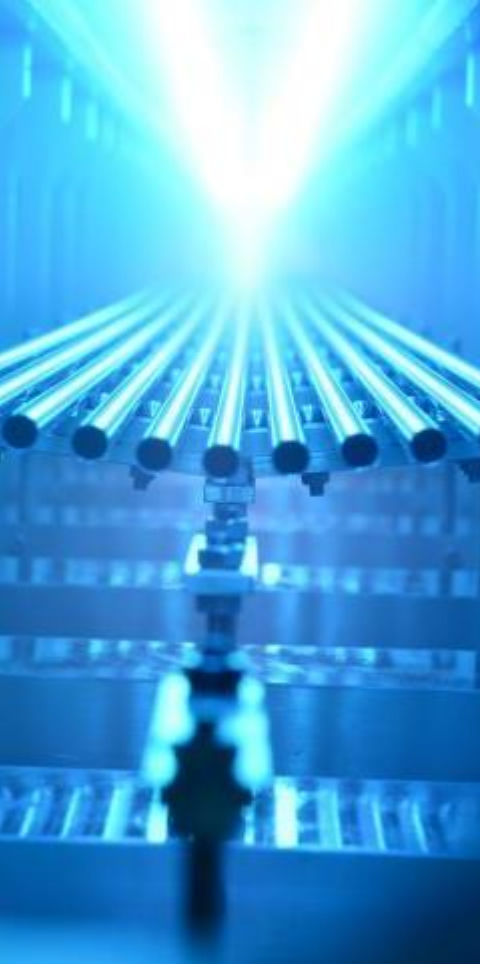
Customer Benefits

- The PROtect near-term solution provides beneficial margin gains for:
 - Design Basis Accident (DBA),
 - BDBA coping time under severe accidents,
 - Activity release in case of leaker; and
 - Resistance to chipping of pellets.
- On the long-term solution a further drastic increase of margin is expected based on SiC material properties
- Fuel economics will be targeted for improvement through increases in uranium utilization.

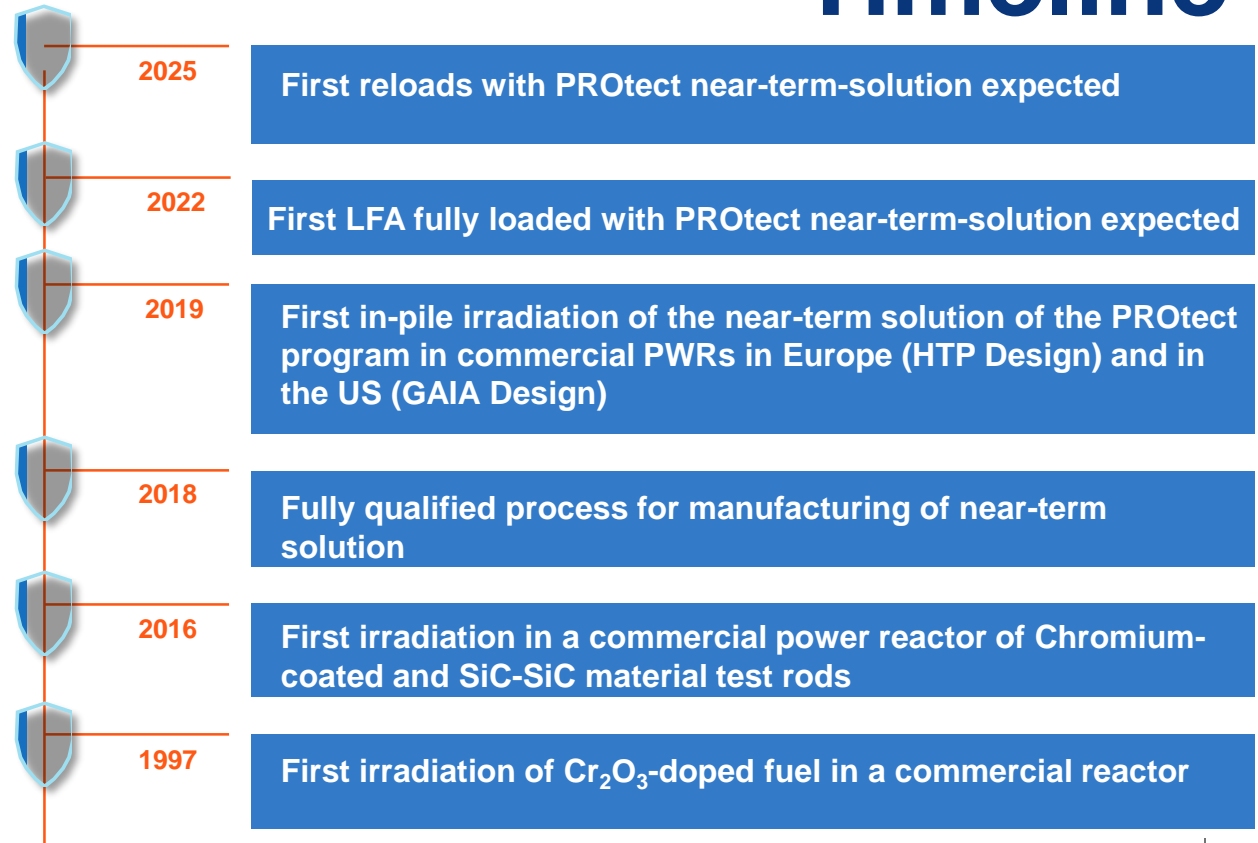


Near-term solution
Chromium-coated rods
+Cr₂O₃-doped fuel.





Timeline



Many thanks to the global team of experts ...



*EATF concepts are developed by the French Institute (CEA, EDF, Framatome)

- 
Federal Agencies
- 
Industry
- 
National Labs
- 
Universities
- 
Utilities
- 
International Agency

Operations and Maintenance Cost Reduction with Data Analytics

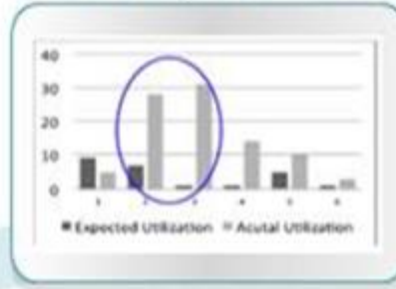
Discovering Insights With Analytics
Analytics = Operationalizing Data

Business Intelligence (BI)



- What happened?
- When, Where & Why?
- How much?

Advanced, Predictive



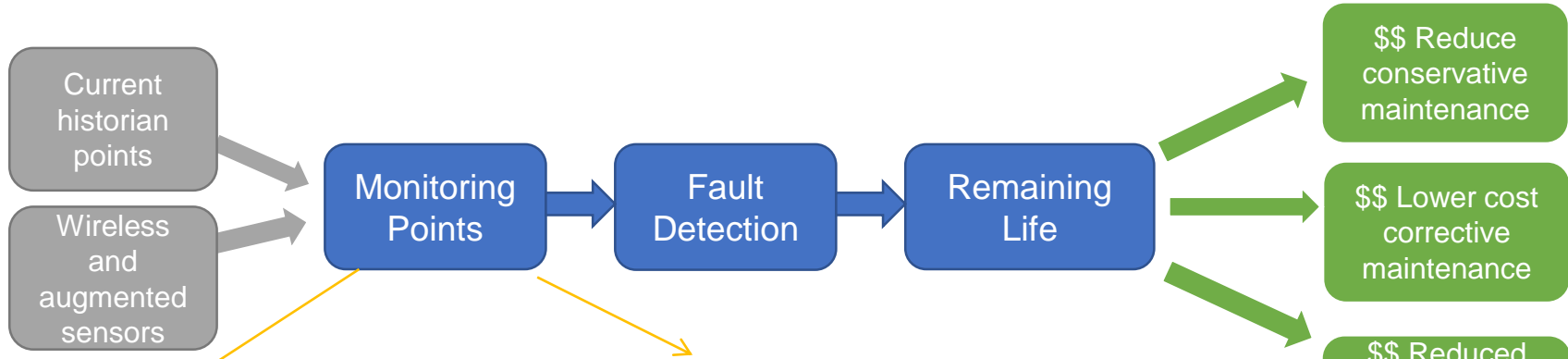
- What could/ will happen?
- What will be the impact?

Prescriptive



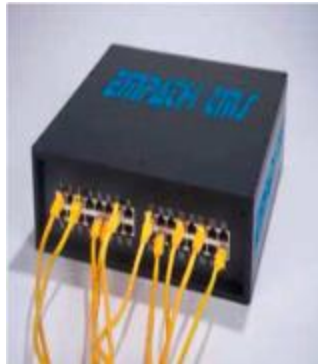
- What are potential scenarios?
- What is the best course of action?
- How can we pre-empt and mitigate the crisis?

Augmented Sensors: Framatome's Empath and Siplug Motor Diagnostics



■ Empath

- Motor Electrical Signature Analysis for up to 32 motors
- Low implementation cost

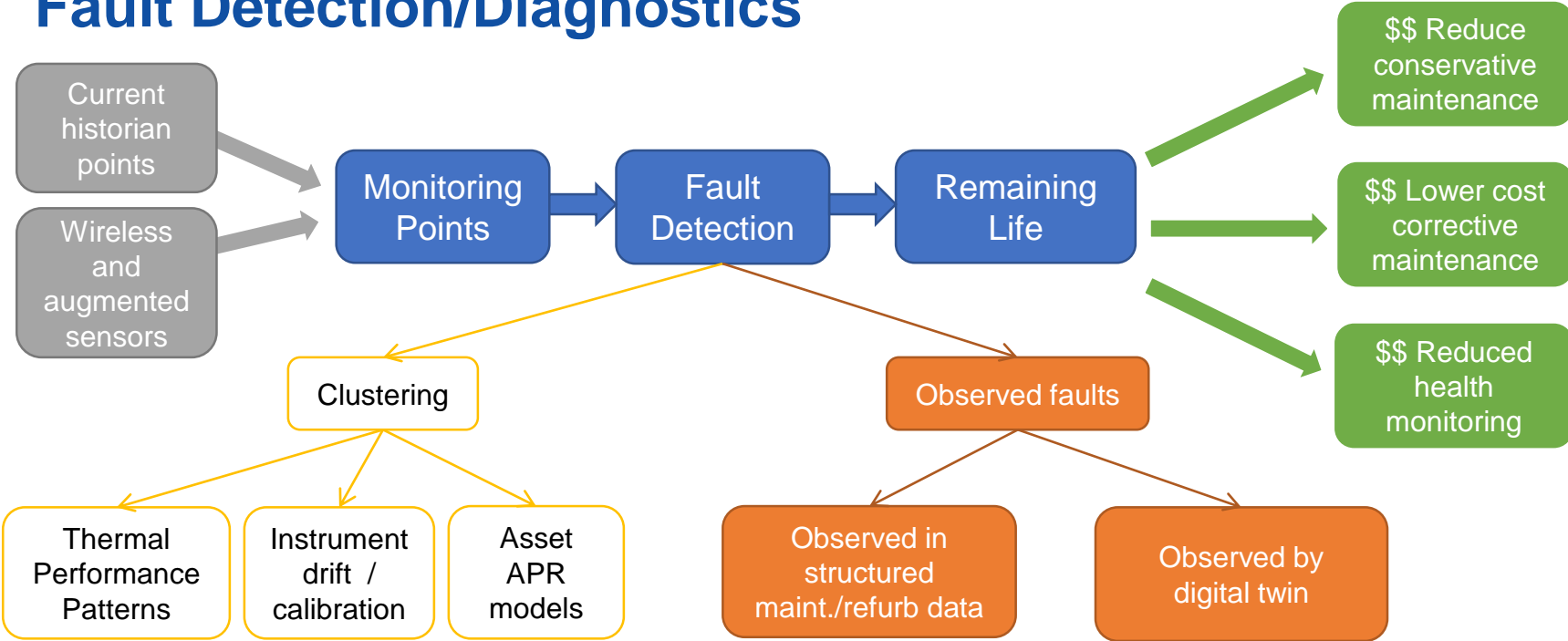


■ Siplug

- Monitoring valve motor actuators
- Uses ADAM analysis software for valve diagnostics

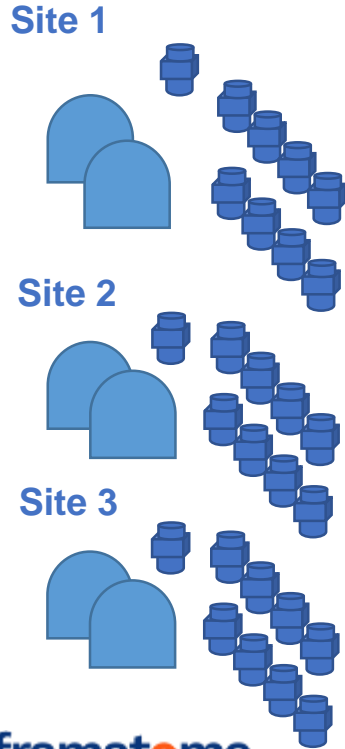


Fault Detection/Diagnostics

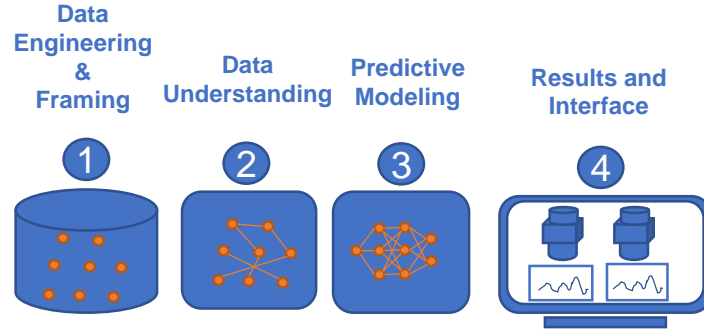


Observed Faults Detection: RCP Motor Refurbishment

Which units / motors?

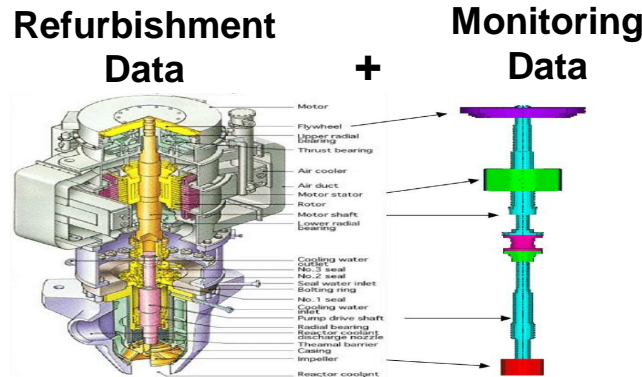


How is the result achieved?



What is delivered?

- A capable set of models for all units
- Real conclusions and supporting software tools delivered and demonstrated on a set of motors
- On-going analytics decision support services and demonstrated return-on-investment



Digital Twin Fault Detection with Metroscope AI

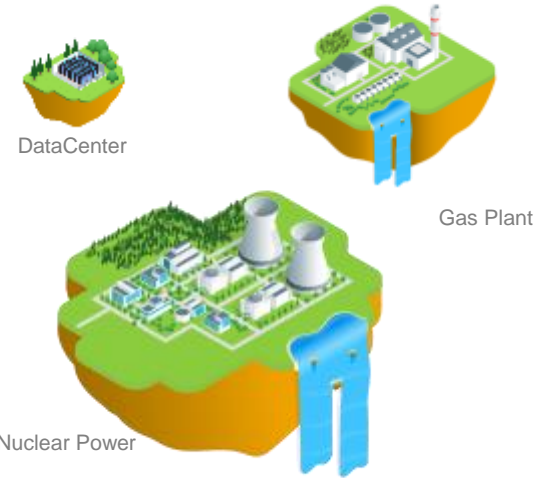
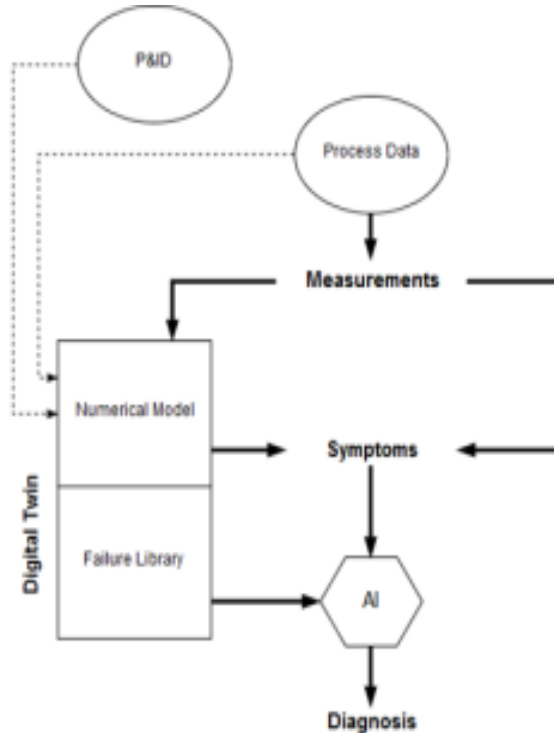


AI Software
Universal Block

Metroscope combines Artificial intelligence and physical simulation

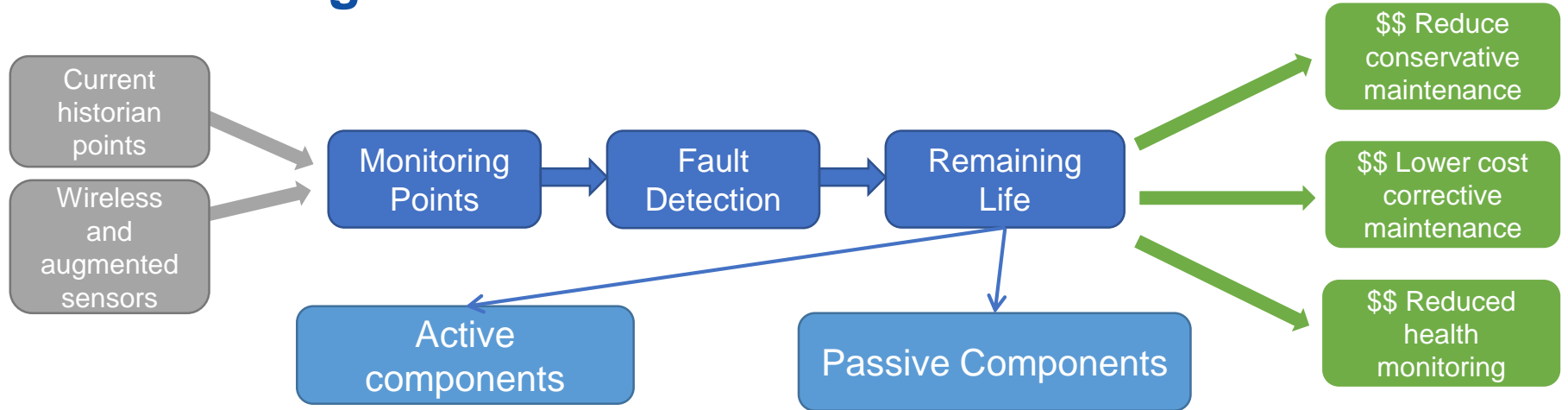
■ METROSCOPE provides a reliable, fast diagnosis of industrial assets.

- The software relies on an unmatched combination of Digital Twin and Artificial Intelligence
- Detect hazards before they impact NPP reliability
- Enhance industrial and environmental performance
- Fix small issues before they become large problems
- Obtain better understanding of the NPP (cause and effects)



Digital twin
Specific block

Remaining Life



- Combine faults and deterministic reliability modeling
- Central Asset Data Intelligence System - is a Framatome data analytics and predictive maintenance platform

- Civil, mechanical, and electrical solution called COMSY (Condition Oriented Aging Management System)
- Developed and used in German market to model passive component aging

What are the potential cost savings?

■ Data Analytics can help reduce NPP costs by:

- Eliminating or reducing unnecessary maintenance and surveillance
- Cost avoidance by predicting failures before they occur
- Extending the life of aging components (extend schedule replacements)
- Improve NPP efficiency by identifying thermal losses
- Lower staffing levels due to reduction in maintenance and surveillance activities





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