ELECTRIC POWER RESEARCH INSTITUTE

EPRI Overview

Jose Antonio Delgado

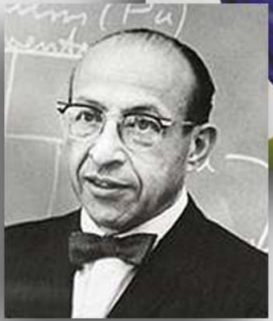
CEIDEN-EPRI Meeting

Madrid

Sept 2014

Electric Power Research Institute (EPRI) History…

- Founded in 1972
- Independent, nonprofit center for public interest energy and environmental research
- **Collaborative** resource for the electricity sector
- Major offices in Palo Alto, CA; Charlotte, NC; Knoxville, TN
- Laboratories in Knoxville, Charlotte and Lenox, MA



Chauncey Starr
EPRI Founder

EPRI | ELECTRIC POWER RESEARCH INSTITUTE

Electric Power Research Institute (EPRI)

EPRI's Mission

To conduct research, development and demonstration on key issues facing the electricity sector on behalf of our members, energy stakeholders, and society

Together…Shaping the Future of Electricity

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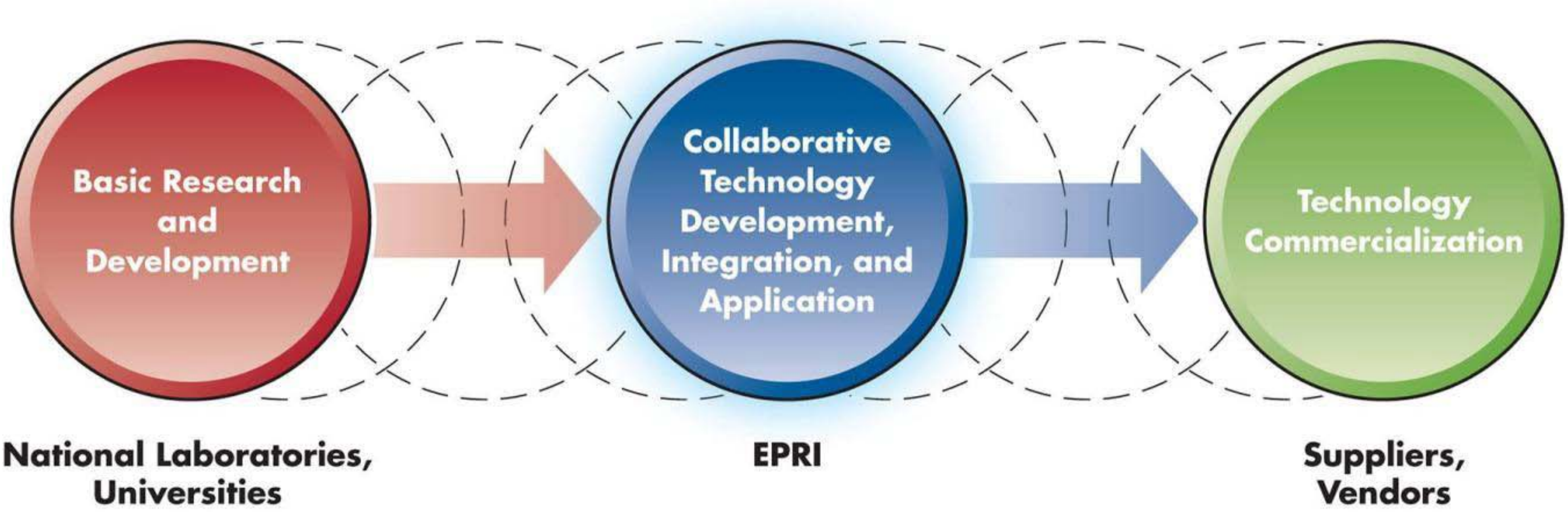
EPRI Role…

Help Move Technologies to the Commercialization Stage…



Technology Accelerator!

Three Key Aspects of EPRI

Independent
Objective, scientifically based results address reliability, efficiency, affordability, health, safety and the environment

Nonprofit
Chartered to serve the public benefit

Collaborative
Bring together scientists, engineers, academic researchers, industry experts

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EPRI R&D Sectors. 2014 Budget: 370M$

Power Delivery and Utilization

- Transmission Lines and Substations
- Grid Operations and Planning
- Distribution
- Energy Utilization
- Cross-Cutting Technologies

Nuclear

- Advanced Nuclear Technology
- Chemistry, Low-Level Waste, and Radiation Management
- Equipment Reliability
- Fuel Reliability
- Long-Term Operations
- Materials Degradation/Aging
- Nondestructive Evaluation and Material Characterization
- Risk and Safety Management
- Used Fuel and High-level Waste Management

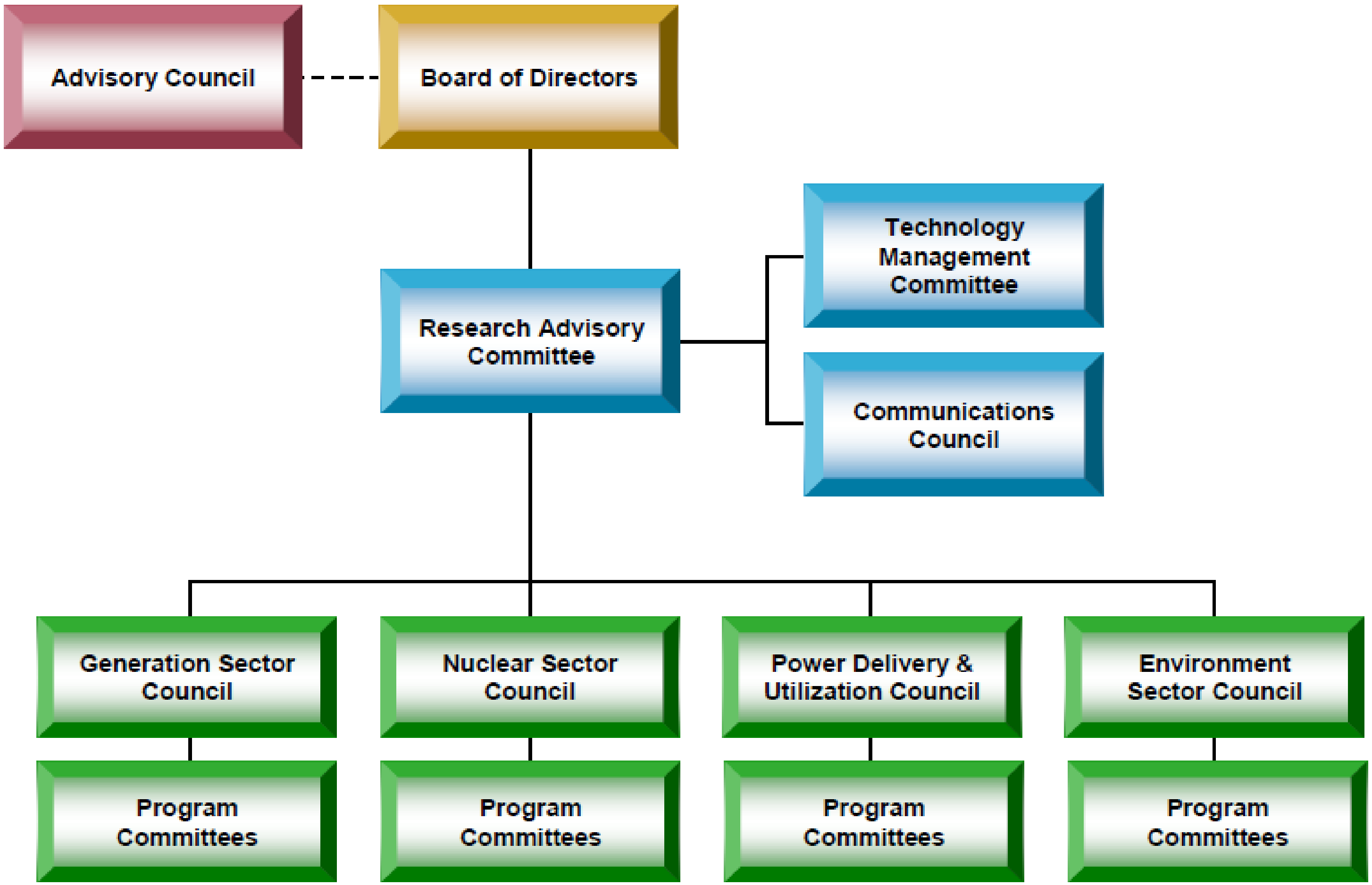
Generation

- Advanced Coal Plants, Carbon Capture and Storage
- Combustion Turbines
- Environmental Controls
- Major Component Reliability
- Materials and Chemistry
- Operations and Maintenance
- Power Plant Water Management

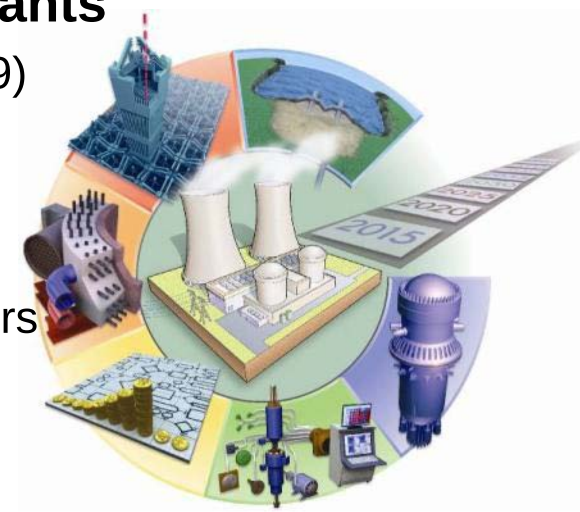
Environment and Renewable Energy

- Air Quality
- Energy and Environmental Analysis
- Land and Groundwater
- Occupational Health and Safety
- Renewable Energy
- T&D Environmental Issues
- Water and Ecosystems

EPRI Top Level Advisory Structure



Spain Membership in EPRI



- **Nuclear UNESA All Spanish Nuclear Power Plants**
  - UNESA is the EPRI member since 2006 (Cofrentes 99)
  - Iberdrola, Endesa, GNF, NN, ANAV, CNAT
  - **ENRESA:** Decommissioning
  - **TECNATOM, GNF**: NDEC, Advanced Nuclear Reactors
- **Generation : Endesa, GNF, Iberdrola**
  - CCGTs, Gas Turbines, HRSGs
  - Coal Plants, Steam Turbines, Boilers, Chemistry
  - Renewables: Solar, Wind, Hydropower (In Environment in 2014)
- **Transmission-Distribution: GNF, Endesa, Iberdrola, Red Electrica**
  - Energy Efficiency, Cybersecurity, Distribution, Electric Transportation
  - Overhead Transmission, Substations

Nuclear Sector Overview

Jean Pierre Sursock

Electric Power Research Institute

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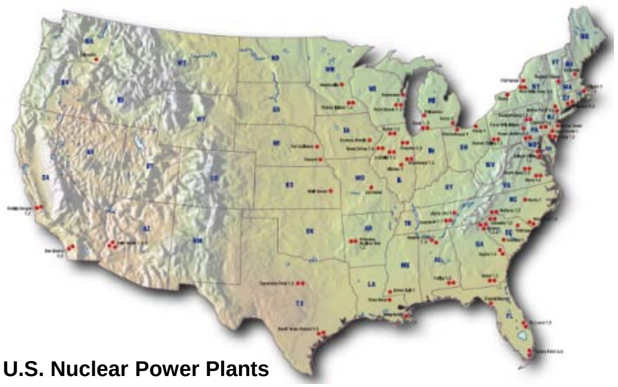
September 2014

OUTLINE of Presentation

- EPRI Nuclear Sector Overview
- Risk and Safety Management
- Material Degradation Program
- Steam Generator Management Program
- Fuel Reliability Program
- Equipment Reliability Program
- Digital Instrumentation and Control

Worldwide Collaboration

U.S. Participants



U.S. Nuclear Power Plants

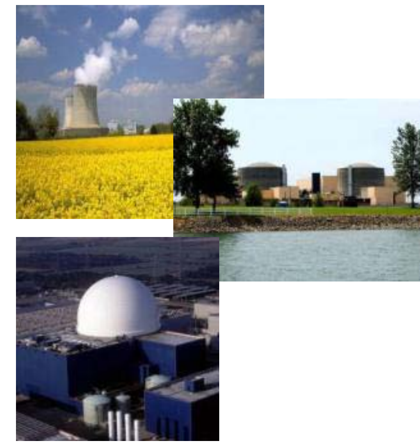
Source: NEI Website, 2009

- All U.S. nuclear owners/operators
- 102 reactors

Non-U.S. Participants

- 20 countries, >220 reactors

Global Breadth and Depth



- >75% of the world's commercial nuclear units

Participants Encompass Most Nuclear Reactor Designs

EPRI Nuclear Membership

FULL Members

- All US Nuclear Utilities
- Candu Owners Group (Canada)
- CEZ (Czech Republic)
- Chubu (Japan)
- Chugoku (Japan)
- CFE (Mexico)
- EDF (France)
- EDF- Energie (UK)
- Eletronuclear (Brazil)
- ENEC (United Arab Emirates)
- ESKOM (S. Africa)
- Kansai (Japan)
- KHNP (Korea)
- NA.SA (Argentina)
- Shikoku (Japan)
- UNESA (Spain)
- TEPCO (Japan)

Participant Utilities

- AXPO (Switzerland)
- BKW FMB Energie (Switzerland)
- CGNPC (China)
- Electrabel (Belgium)
- Hokkaido Japan
- Hokuriku (Japan)
- Kyushu (Japan)
- JAPC (Japan)
- J-Power (Japan)
- Slovenske Elektrarne (Slovakia)
- Taipower (Taiwan)
- Tohoku (Japan)
- Vattenfall/OKG (Sweden)

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International R&D Partnerships

Active Collaboration with Global Research Institutes, National Laboratories, Universities and Vendors

NUGENIA
NUclear GENeration II & III Association

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IBERDROLA

tecnatom

EDF

ÚJV ÚJV Řež, a. s.

U.S.NRC

U.S. DEPARTMENT OF ENERGY

OECD NEA

AREVA

PAUL SCHERRER INSTITUT PSI

CRIEPI

Massachusetts Institute of Technology

cea

KHNP Nuclear Engineering & Technology Institute

IAEA.org International Atomic Energy Agency

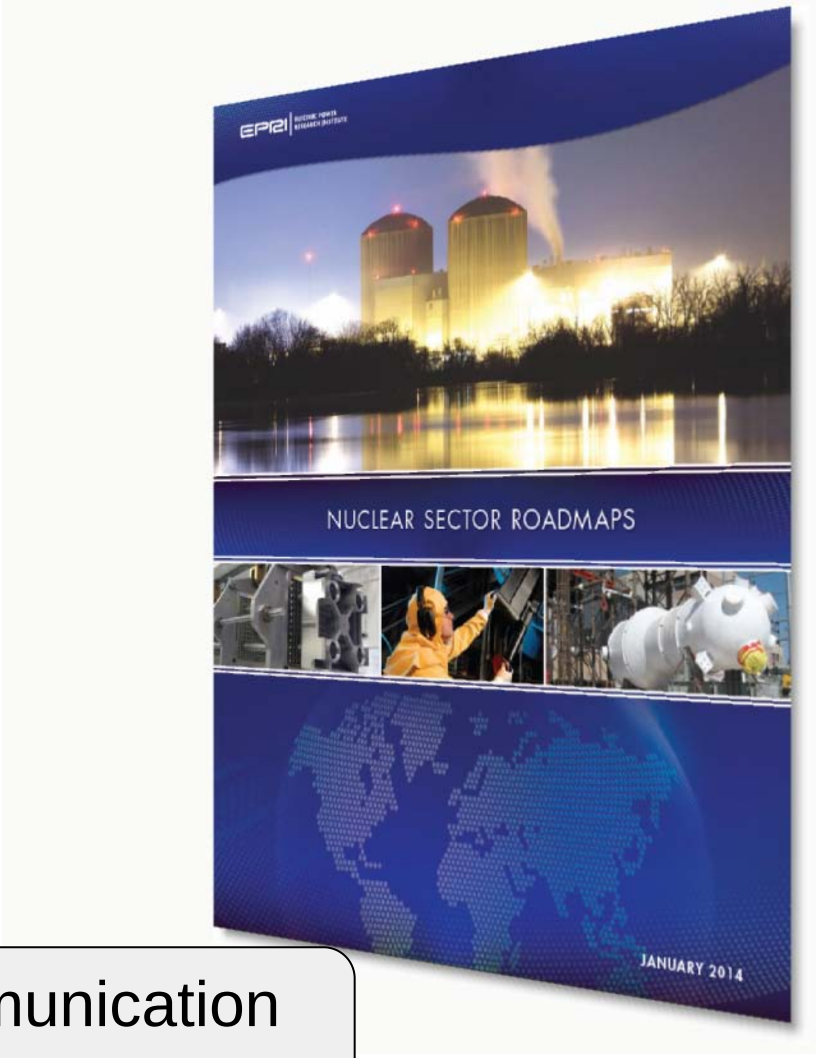
the materials ageing institute

Nuclear Industry Drivers

Risk and Safety	• Risk and Safety Program • Fuel Reliability Program • Materials Degradation
Performance and Cost	• Material Reliability • Equipment Reliability • Non Destructive Examination
Plant Life Extension	• Long Term Operation • Material Aging • Instrumentation and Control
Waste Storage & Disposal	• Low Level Waste • High Level Waste • Decommissioning
New Builds	• Advanced technologies • Design optimization • Construction cost control

The EPRI Nuclear Roadmaps

- What should EPRI be doing?
- When does it need to be done?
- How do projects fit together to address issues?
- How does EPRI work fit in the bigger picture?
- What Resources are needed?



Management and Communication Tool

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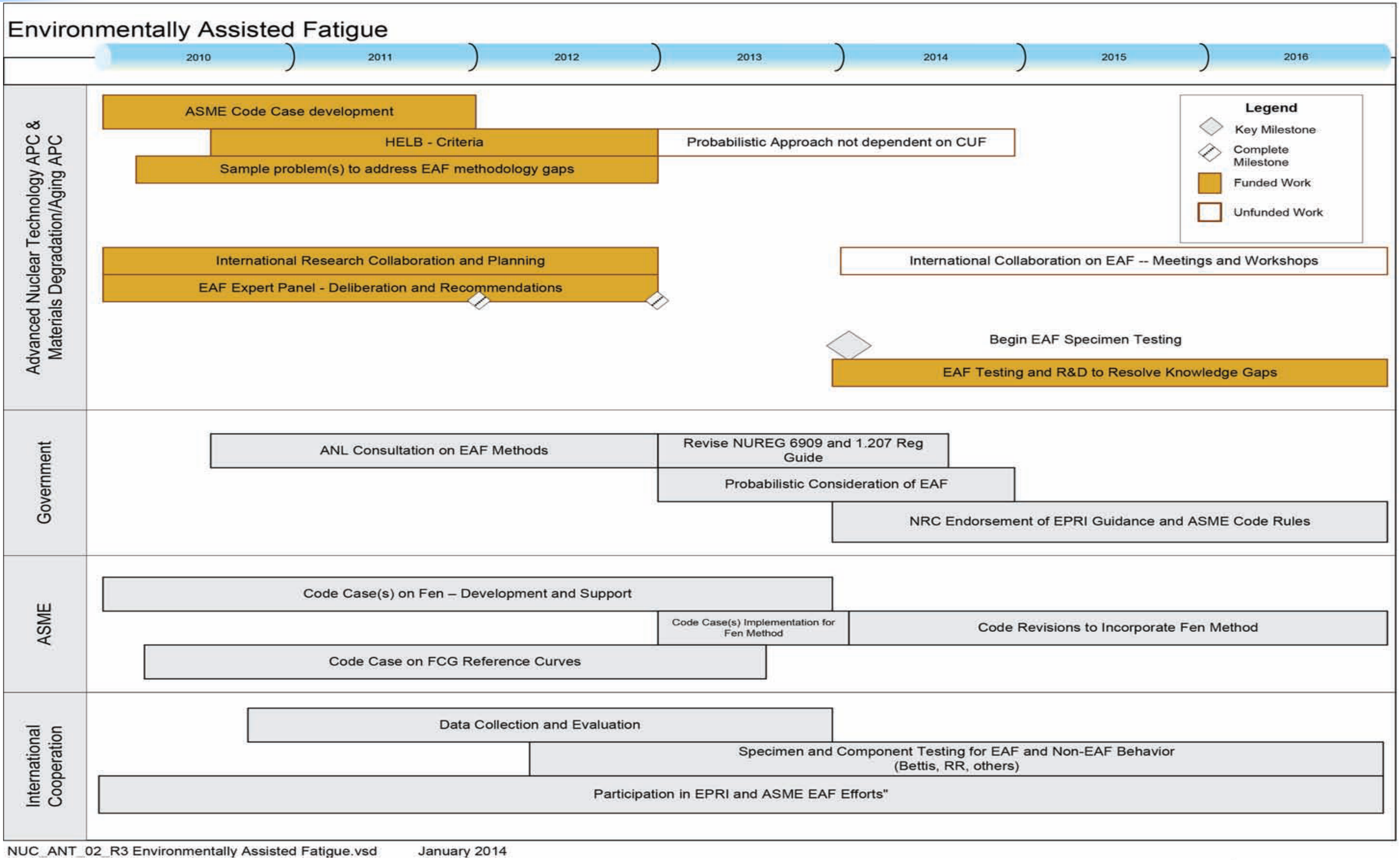
Example of EPRI Nuclear Roadmap



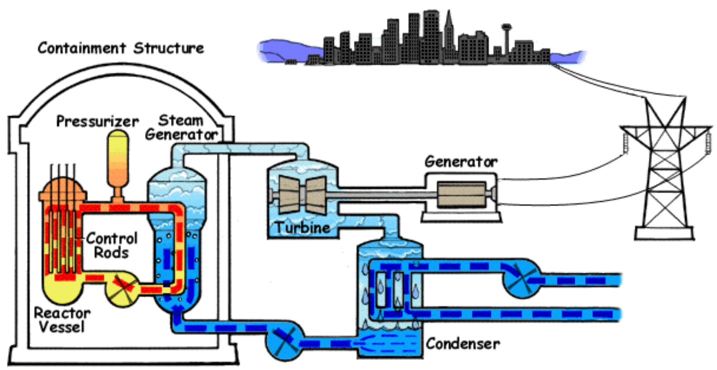
Scope of Nuclear Program ($170 M/year)

Material Degradation/Aging
- Corrosion Research
- BWR Materials (BWRVIP)
- PWR Materials Reliability (MRP)
- SG Management
- Welding & Repair Technology

Fuel Reliability
- Fuel Reliability Program
- NFIR

High Level Waste/Spent Fuel
- Spent Fuel Storage & Transport
- Advanced Fuel Cycle

Low Level Waste & Radiation Exposure Management
- Low Level Waste Management]
- Rad Exposure Management
- Decommissioning Technology
- Groundwater Management
- Water Chemistry



Long-Term Operation

Non-Destructive Evaluation
- NDE Technology
- Performance Demonstration (PD)

Advanced Nuclear Technology
- New Nuclear Plant Deployment
- Advanced Technologies

Safety & Asset Risk Mgmt.
- Risk Mgmt.
- Deterministic safety
- Fukushima

Equipment Reliability
- Nuclear Maintenance App.
- Plant Engineering
- Balance of Plant Corrosion
- Integrated Life Cycle Management
- Instrumentation & Controls

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Risk and Safety Management

Risk and Safety Management

Risk Informed Methods

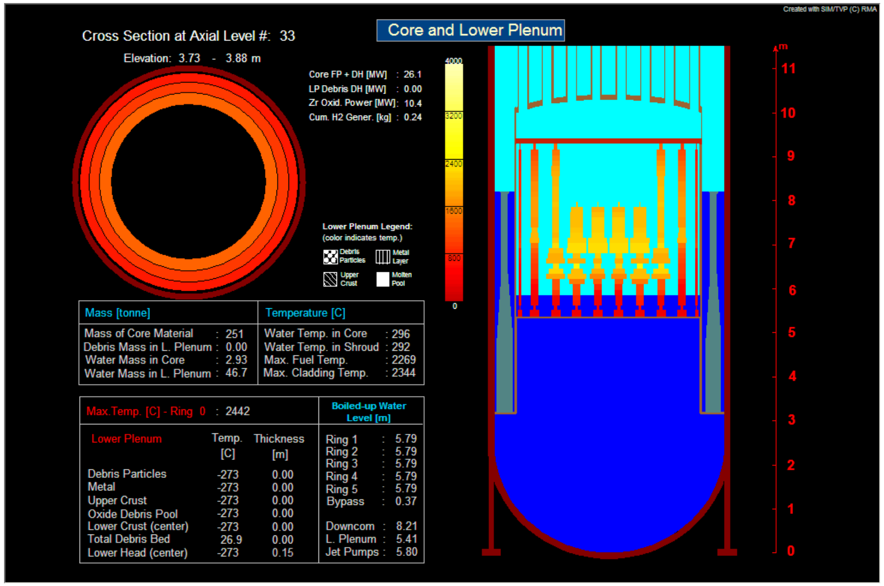
- Risk Tools & Models
- Configuration Management
- External Events
- Low Power & Shutdown
- Fire & Seismic PRA

Deterministic Safety

- Severe Accidents
- RCS System Modeling
- Fire Database
- Seismic Databases
- Thermal Hydraulics

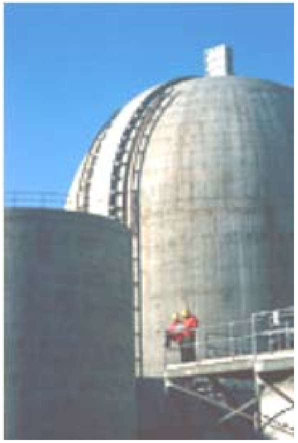
MAAP5: System Code for Abnormal Transients and Severe Accidents

- Simulates the response of integrated nuclear plants during severe accidents
  - Core thermal-hydraulic performance
  - Containment performance
  - Fission product transport and release

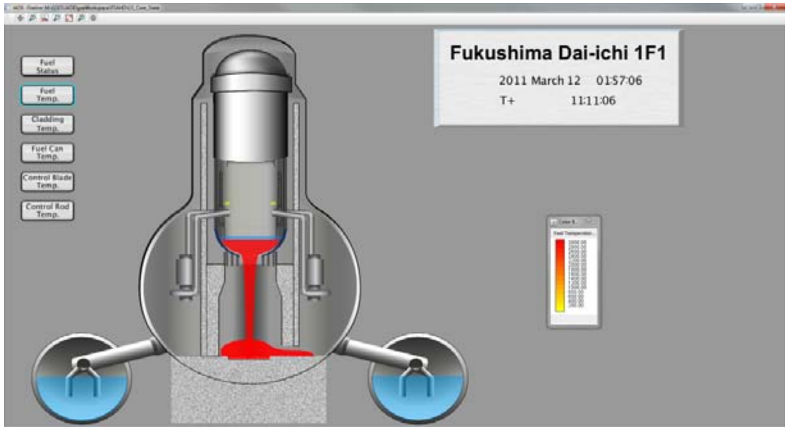


- <u>Fast running</u> code to predict the accident progression
- Predict timing of key events (e.g., core uncovery, damage, vessel breach)
- Evaluate effects of operator actions
- Predict magnitude and timing of fission product release

Current Applications of the MAAP Code



- Probabilistic Risk Assessment (PRA)
- License Renewal/Power Uprates
- Design & Design Certification for Advanced Light Water Reactors
- Severe Accident Guidelines (1992)
- Severe Accident Simulators



- Fukushima Root Cause Evaluation
- Severe Accident Guidelines (2013)
- Filter and Venting Strategies
- Stress Tests
- Restart Analyses in Japan
- Portable Equipment/FLEX
- Spent Fuel Pool Analyses
- Real-Time Event Evaluations

External Events Risk Assessment

Hazards Assessment

- Hazard screening techniques
- External event data collection

Improved PRA methods

- Seismic events
- External flooding
- High winds
- Fire

Overview – External Event Analysis

Identify relevant hazards

- *Screen unimportant events*
- *Select events for analysis*

↓

Evaluate probabilistic hazard

- *Frequency of occurrence*
- *Magnitude of event*

↓

Analyze impact on plant/systems

- *Plant response*
- *“Fragility” analysis*

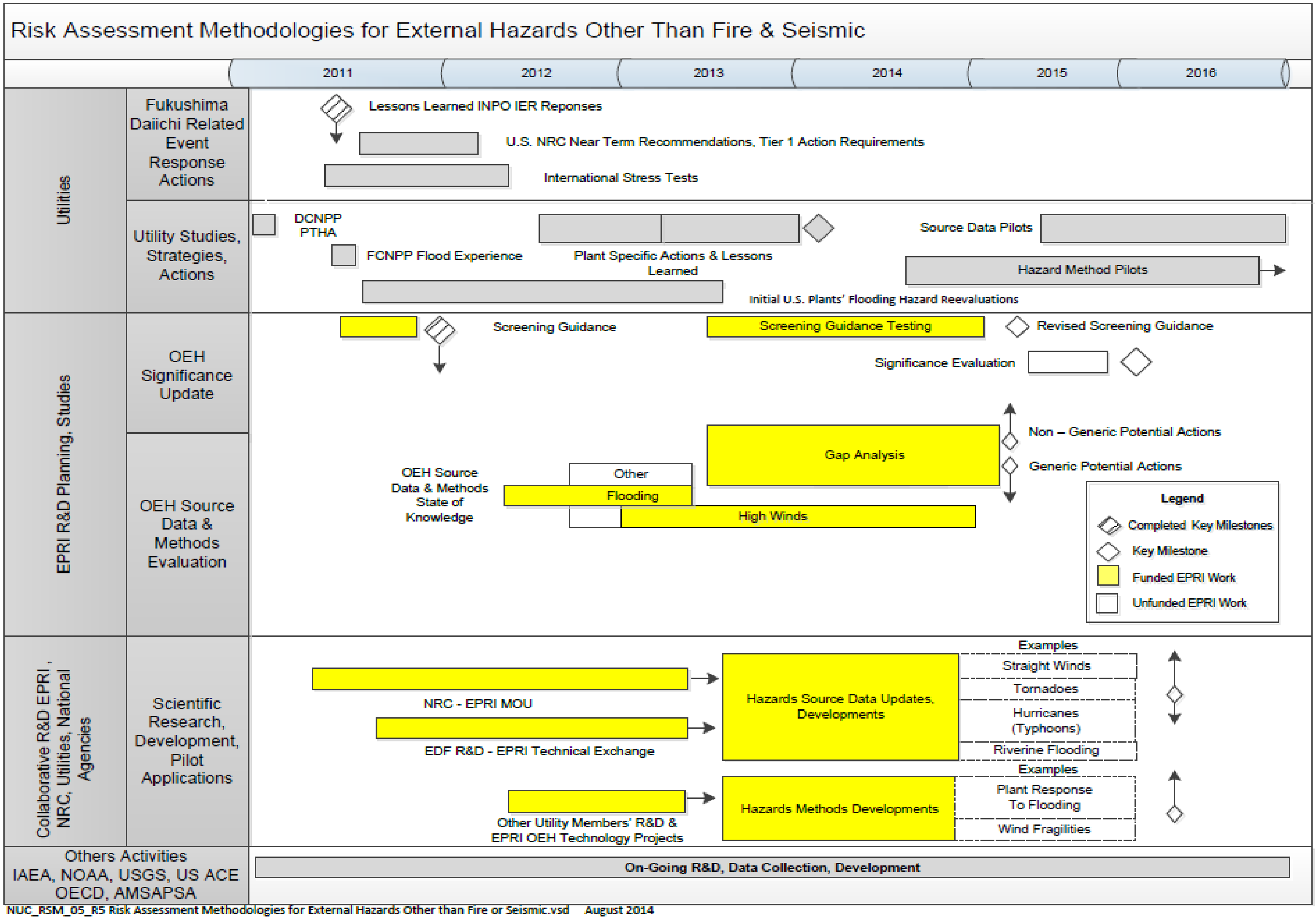
↓

Incorporate effects into PRA

- *Adapt event and fault trees*
- *Quantify risk*

Other External Hazards (OEH) Roadmap

(Hazards Other than Seismic, Internal Fire and Internal Flooding)



Key Elements of High Winds R&D Plan

- Develop methods and data to characterize wind hazards
  - Characterize phenomena (tornadoes, hurricanes, straight-line winds)
  - Characterize vulnerabilities of safety significant SSCs
- Characterize response (fragilities) of SSCs exposed to high wind loading and wind driven missiles
- PRA modeling guidance
- Develop / enhance wind hazard analysis tools

Multi-Hazards Risk Aggregation (MHRA)

- Risk analysis involves many sources of initiating events, normally analyzed in separate probabilistic risk assessments
- MHRA is typically performed by summing the mean value contributions to the risk metrics (e.g. CDF, ΔCDF) from the various contributing hazards PRAs
- Industry's main concern is whether summing the contributions is valid
- PRAs for the different hazard groups produce results that are not necessarily equivalent

Steps to Address Aggregation Concerns

- Parameter Uncertainties: Perform sensitivity studies – Develop new math techniques (RSM)
- Model Uncertainties: Compile list of the issues in modeling for the various hazard contributions
  - Completeness issues
  - Unnecessary Conservatisms
  - Basically irresolvable
- Develop guidelines to address parameter and model uncertainties that challenge the acceptance criteria, e.g.
  - Can the conservatism be countered by factors not taken into account in the PRA analysis? (e.g. FLEX, HRA)
  - Qualitative demonstration of sufficient defense-in-depth.

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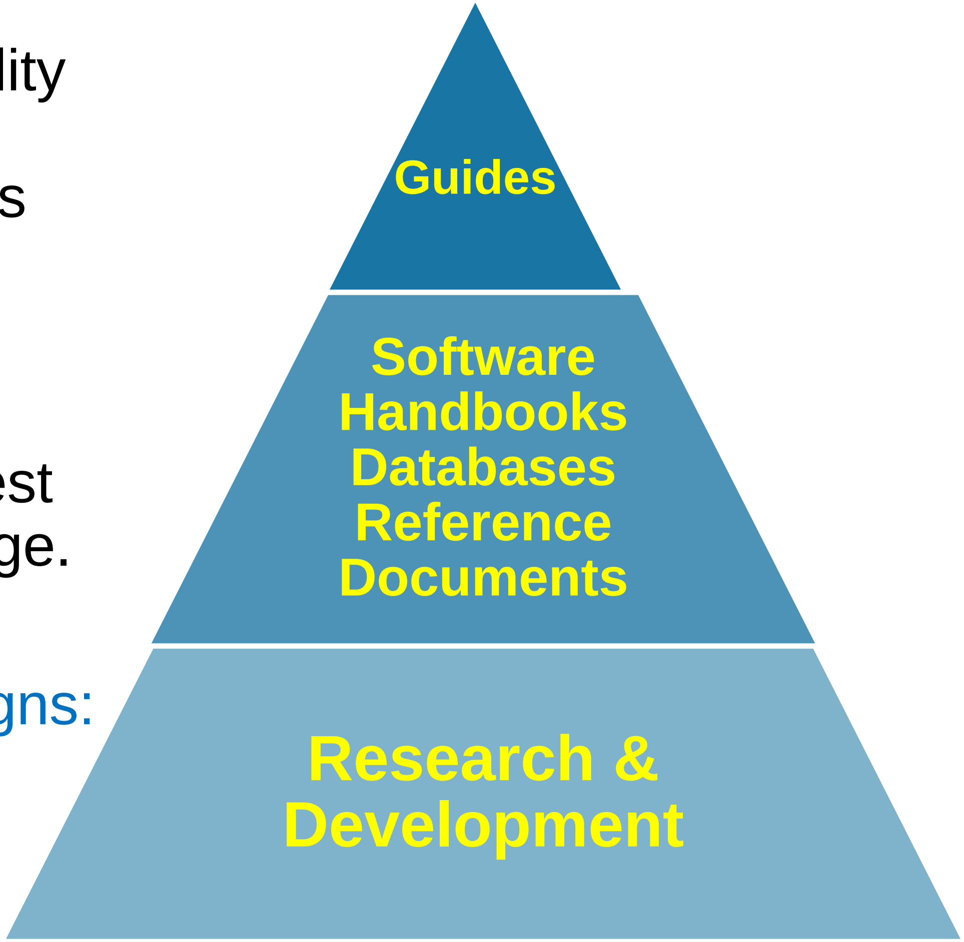
Fuel Reliability Program

Fuel Reliability Program (RFP): Strategic Objectives & Approach

1. Operational Issues: Drive improvements in fuel reliability and performance and reduce/eliminate fuel failures

2. Regulatory issues: Inform debate to ensure that regulations are based on best available technical knowledge.

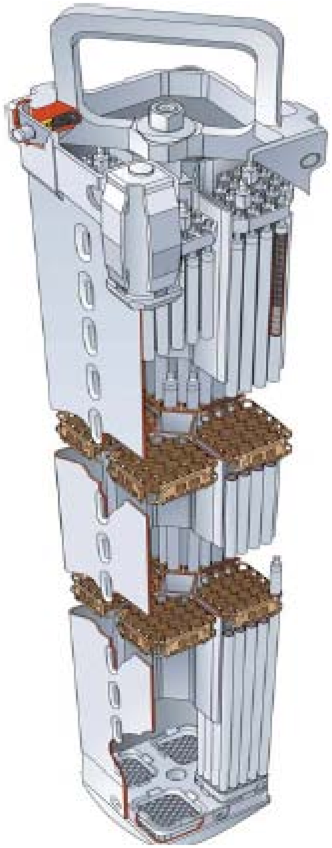
3. Advanced nuclear fuel designs: Research materials for Accident tolerant Fuels in existing plants



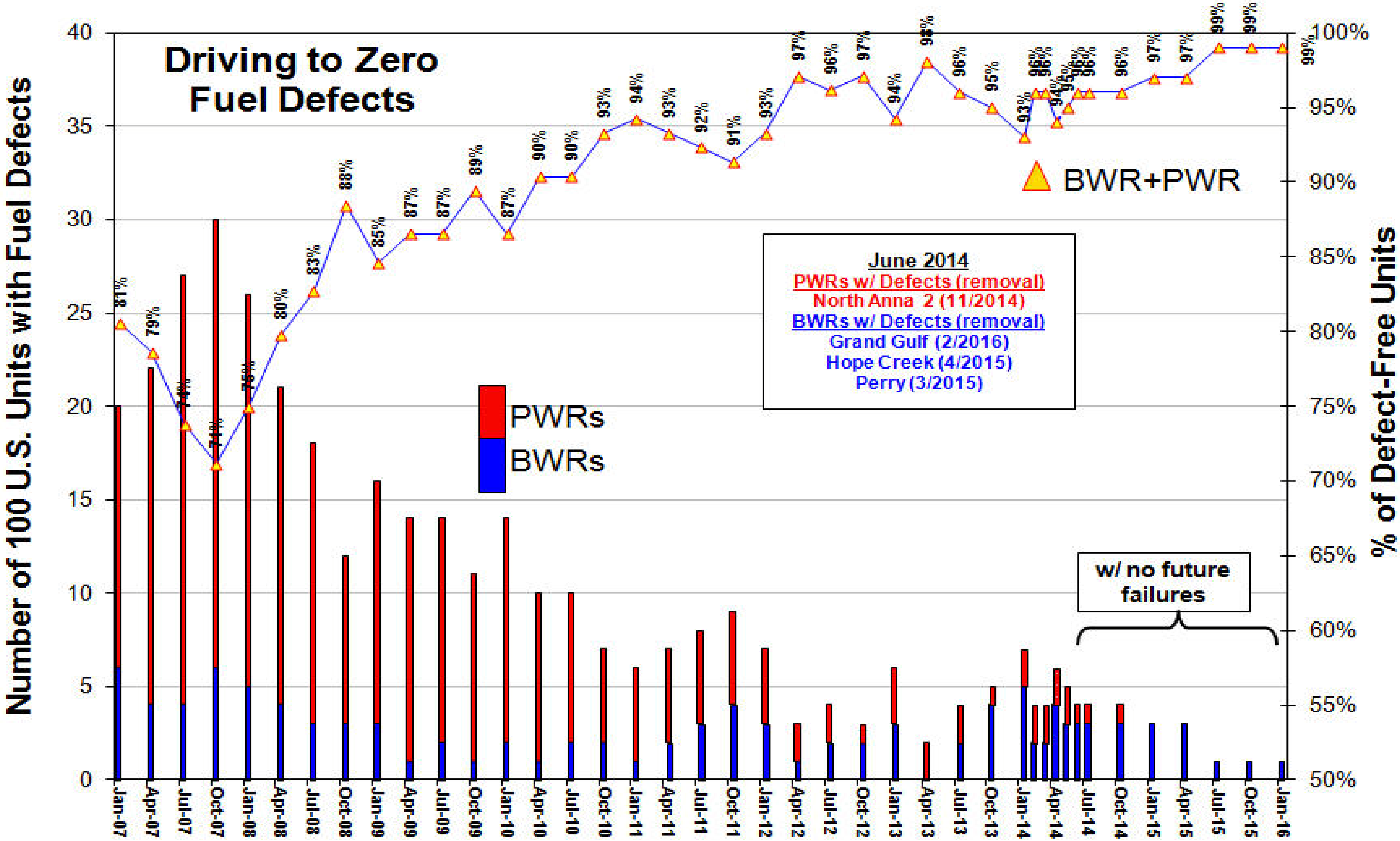
Key RFP Products to Support Zero Fuel Failures

- **Fuel Guidelines**
  - Fuel Surveillance and Inspection
  - BWR Fuel Cladding Corrosion and Crud
  - PWR Fuel Cladding Corrosion and Crud
  - PWR Grid-to-Rod Fretting
  - Pellet - Cladding Interaction

- **Other Important References**
  - Fuel Reliability Database (FRED)
  - Fuel Reliability Monitoring and Failure Evaluation Handbook
  - Fuel Design Evaluation Handbook
  - Falcon Fuel Performance Code
  - Boron-induced Offset Anomaly (BOA) Risk Assessment Tool



US Industry Nuclear Fuel Failure Rates



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Requirements for Accident Tolerant Fuel Cladding

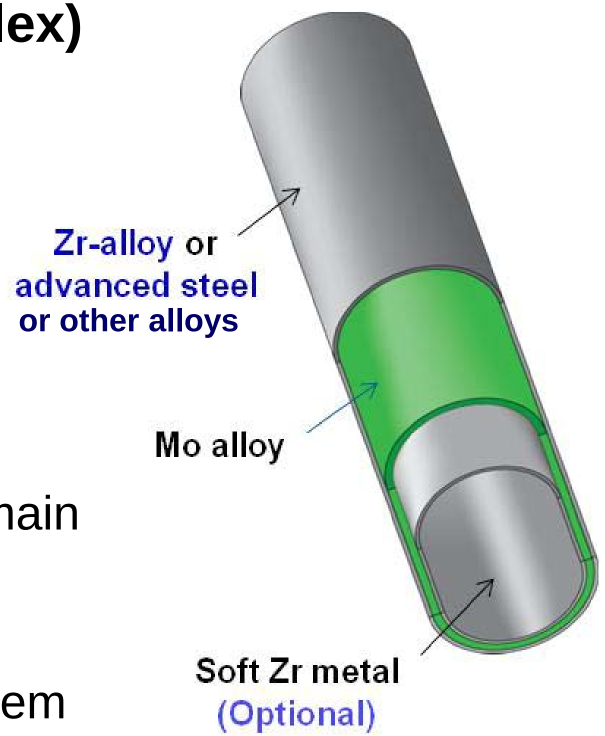
- Good high temperature properties:
  - high melting temperature
  - adequate cladding tensile & creep strength at 1200-1500^{o}C
  - Resistance to steam (+hydrogen) corrosion at 1200-1500^{o}C
- Viable economics
  - Acceptable neutronic absorption cross sections
  - Material available at reasonable costs
- Fabricable into full length cladding tubes
  - Can be hermetically sealed
- Compatible with current LWR designs and coolants
- Good fuel reliability under normal operation
- No fuel storage and disposal issues

Molybdenum Alloy Cladding Design Concepts

- Utilizing Mo alloys' unique properties:
  - Tensile and creep strength at 1000-1800^{o}C
  - High stability in reducing and inert environments to ~2000^{o}C
  - Fabricability into long, thin wall tubes
  - Can be welded to end caps
- Challenges for LWR fuel applications:
  - Higher neutron absorption cross sections than Zr; cladding wall thickness needs to be reduced (<0.25 mm)
  - Reacts with high temperature steam; needs improvement/protection
  - Irradiation embrittlement is known and needs further evaluation
  - Industry infrastructure for Mo cladding not well established
  - R&D needed to support industrial applications

Mo-Alloy Based Cladding for LWR Accident Tolerant Fuel Designs

- **Thin-wall Mo alloy tube protected by Zr alloy or advanced steel on the OD surface (duplex)**
- **Mo inner surface protected by a soft Zr alloy or others (a thin stable oxide) as an option (triplex)**
- **May achieve**
  - Accident tolerance to 1200-1500ºC
  - Maintain fuel rod integrity
  - Eliminate design base LOCA issues
- **Monolithic Mo alloy cladding?**
  - Reaction with oxygen at elevated temperature is main challenge - requires substantial R&D effort on corrosion resistance and ductility
  - May open up a unique high temperature alloy system for many applications



Material Reliability and Steam Generator Management

PWR Material Reliability Program: Scope

- Reactor Internals
  - Inspections for aging management
  - Visual Examinations of void swelling
  - Tracking field data
  - Guidance for mitigation
  - Repair & Replacement Strategies

- Reactor Pressure Vessel
  - Doel-3 related concerns (foreged ring vessels)
  - P-T curve: potential non-conservatism
  - Thermal Shock
  - High Fluence embrittelement (extended beltline)

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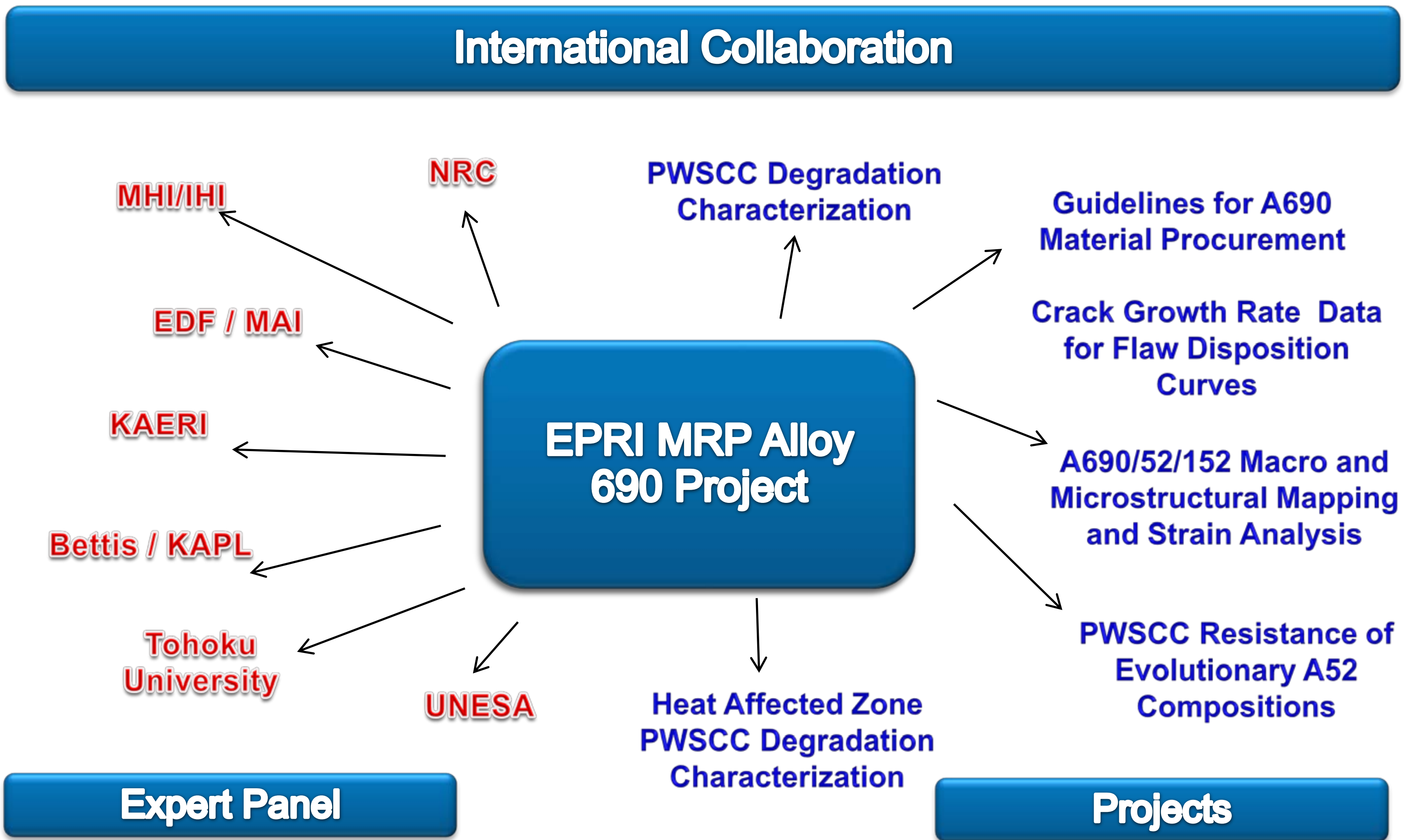
PWR Material Reliability Program: Scope (cont.)

- Fatigue Degradation
- Irradiated Materials
  - Uncertainties and conservatisms
  - Exposure levels, chemistry, temperature, neutron spectrum, …
- Nickel-based alloys (690 and 600 PWSCC))
  - SCC testing and modeling
  - Inspection
- Stainless Steel degradation

MRP Research Area: Alloy 690



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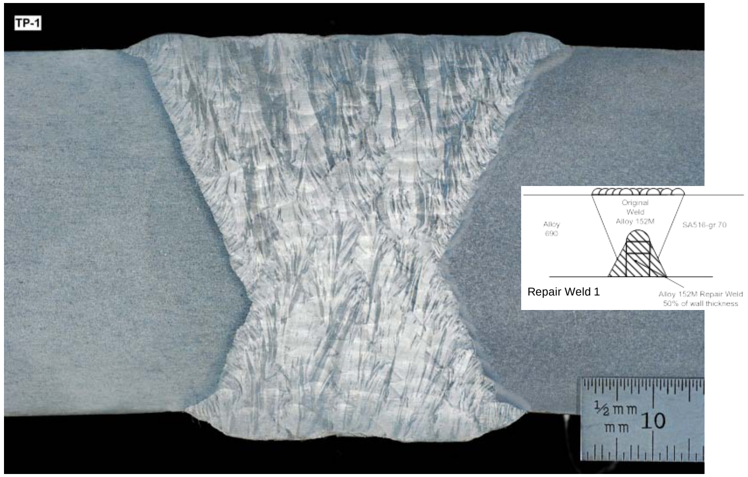
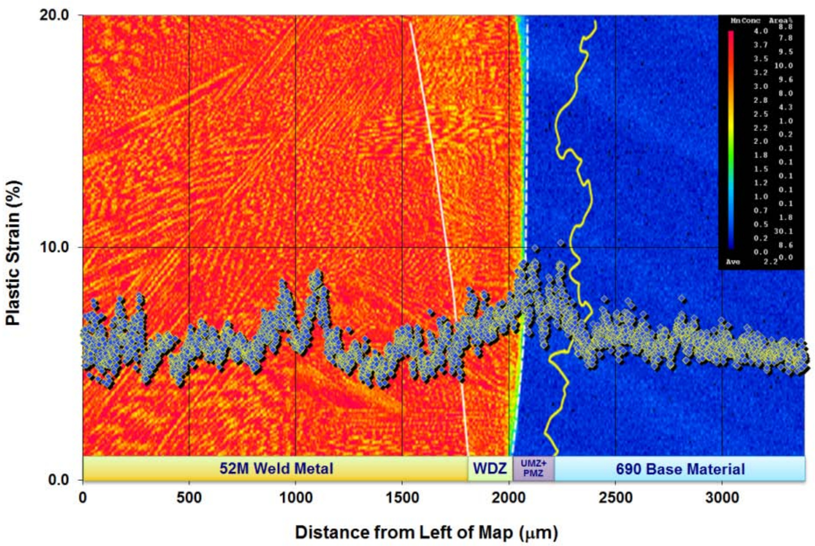
MRP Research Area: Alloy 690

- Testing and field experience confirm high PWSCC resistance of Alloys 690/52/152
- Work substantiates technical basis for optimized inspection of A690 replacement components such as the reactor pressure vessel head
- More extensive work explored or underway to further understand
  - Vulnerability to abnormal microstructure and to welding residual stresses and strains
  - Role of weld imperfections in initiation and growth of PWSCC





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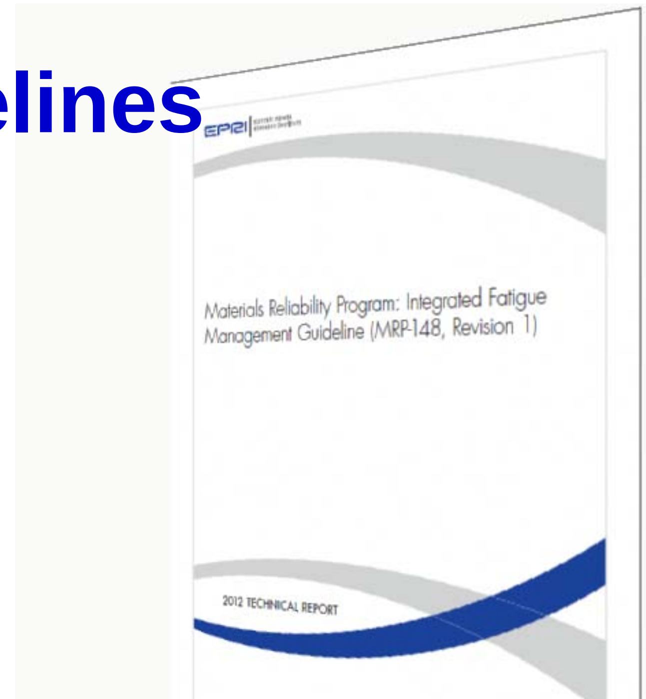
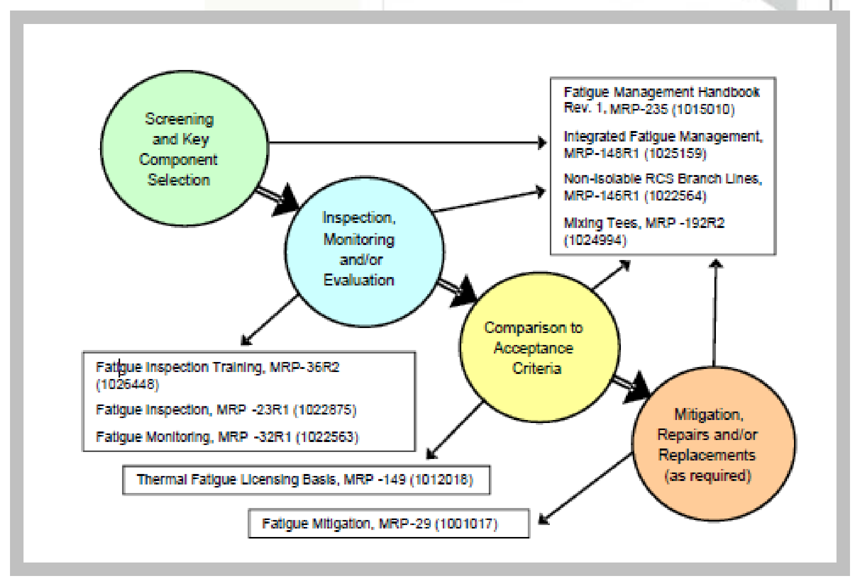
Fatigue Management Guidelines

- Fatigue Management Handbook
- Integrated Fatigue Management
- Non-Isolable RCS Branch Lines
- Mixing Tees
- Fatigue Inspection Training
- Fatigue Inspection
- Fatigue Monitoring
- Fatigue Mitigation
- Thermal Fatigue Licensing Basis





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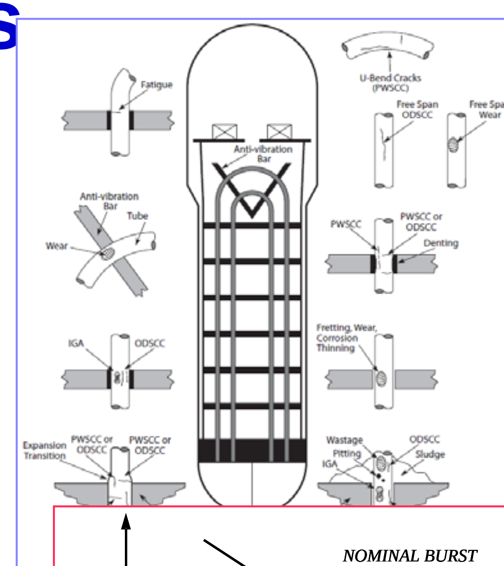
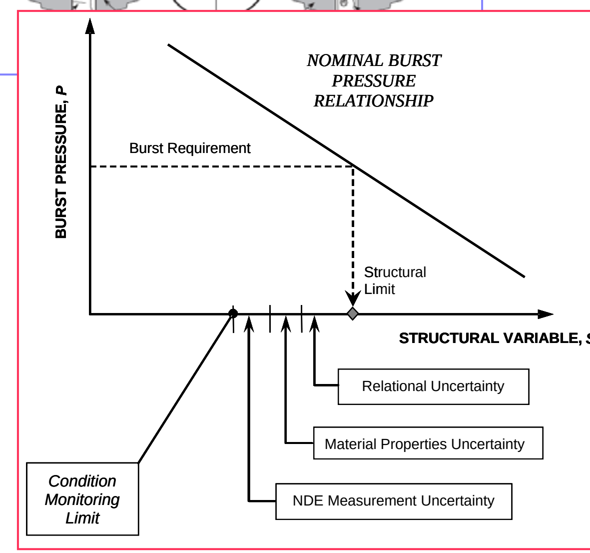
Steam Generator Guidelines

- **Examination Guidelines**
  - Identification of degradations affecting SG tube integrity
  - Qualification of NDE systems used to detect and/or size degradation
- **Water Chemistry Guidelines**
  - Primary & Secondary
- **Primary to Secondary Leak Guidelines**
  - Optimized leak rate calculations and operator actions
- **Tube Integrity Guidelines**
  - evaluating SG tubes based on inspection data and guide integrity assessments





Periodic revisions based on lessons learned from worldwide operating experience and R&D advances

BWRs: Inspection Optimization

- Large number of inspections required for BWR vessel, internals and piping
- BWRVIP Inspection and Evaluation (I&E) guidelines developed using
  - best available knowledge
  - Worldwide operating experience

Component	I&E Guidelines
Core Shroud	BWRVIP-76-A
Core Spray	BWRVIP-18, R1-A
Shroud Support	BWRVIP-38
Top Guide	BWRVIP-26-A
Core Plate	BWRVIP-25
Standby Liquid Control System	BWRVIP-27-A
Jet Pump Assembly	BWRVIP-41, R3
CRD Guide/Stub Tube	BWRVIP-47-A
In-core Housing/Dry Tube	BWRVIP-47-A
Instrument Penetrations	BWRVIP-49-A
LPCI Coupling	BWRVIP-42, R1
Vessel ID Brackets	BWRVIP-48-A
Reactor Pressure Vessel	BWRVIP-74-A
Primary System Piping	BWVIP-75-A
Steam Dryer	BWRVIP-139-A
Access Hole Cover	BWRVIP-180
Top Guide Grid Beam	BWRVIP-183
Bottom Head Drain Line	BWRVIP-205

Technical Highlight
Materials Degradation Matrix

MDM Covers every:

- •Component
- •Material
- •degradation mechanism
- •gap in our understanding

	DEGRADATION MODE													
	Corrosion				Wear	SCC		Fatigue		Reduction in Fract Properties		Irradiation Effects		
MATERIAL	Wstg	Pitting	FAC	Foul	Wear	IG/TG	IA	HC	EAF	Th	Env	Emb	VS	IC / SR
C&LAS: Base Metal & HAZ	N	N	Y b1-3a	N	N	Y b1-6a	$?^{LTO}$ b1-7a	Y^{IMP} b1-8a	Y^{LTO} b1-9a	N	Y b1-11a	Y^{LTO} b1-12a	N/A	N
C&LAS: Welds	N	N	Y b1-3b	N	N	Y b1-6b	$?^{LTO}$ b1-7b	Y^{IMP} b1-8b	Y^{LTO} b1-9b	N	Y b1-11b	Y^{LTO} b1-12b	N/A	N
SS: 300 Series SS Base Metal & HAZ	N	N	N	N	N	Y b1-6c	N	Y^{IMP} b1-8c	Y^{LTO} b1-9c	N	Y b1-11c	N	N/A	N
SS: 300 Series Welds & Clad	N	N	N	N	N	Y b1-6d	N	Y^{IMP} b1-8d	Y^{LTO} b1-9d	Y b1-10d	Y b1-11d	Y b1-12d	N/A	N
Cast Austenitic Stainless Steel	N	N	N	N	N	Y b1-6e	N	N	Y^{LTO} b1-9e	Y b1-10e	Y b1-11e	N	N/A	N
Ni-Alloy: A600 Base Metal & HAZ	N	N	N	N	N	Y^{LTO} b1-6f	N	N	Y^{LTO} b1-9f	N	Y b1-11f	N	N/A	N
Ni-Alloy: A182 Welds & Clad	N	N	N	N	N	Y^{LTO} b1-6g	N	N	Y^{LTO} b1-9g	N	Y b1-11g	N	N/A	N
Ni-Alloy: A82 Welds & Clad	N	N	N	N	N	Y^{LTO} b1-6h	N	N	Y^{LTO} b1-9h	N	Y b1-11h	N	N/A	N
Ni-Alloy: A52/152 Welds & Clad	N	N	N	N	N	N	N	N	Y^{LTO} b1-9i	N	Y b1-11i	N	N/A	N

Global Relevance: 2013 revision included CANDU, 2014 VVER

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Equipment Reliability

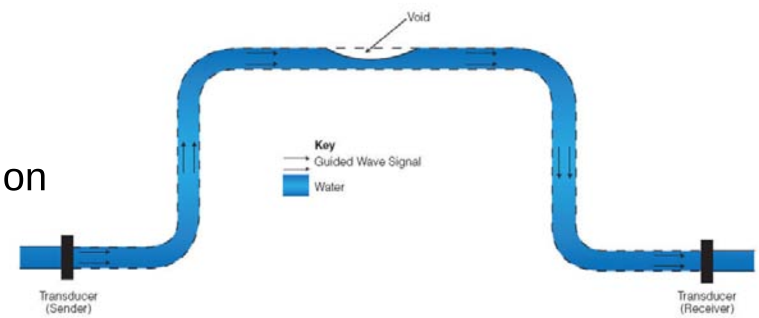
Equipment Reliability

Maintenance	Engineering	Instrumentation & Control
• Maintenance Guides • Maintenance Databases • Users Groups • Respond to Industry Issues	• BOP Corrosion • Cable Aging • Pipe Integrity • Procurement • Plant thermal performance • CB Training	• Plant performance • Digital technology challenges • Control room tools • Wireless com • Smart sensors

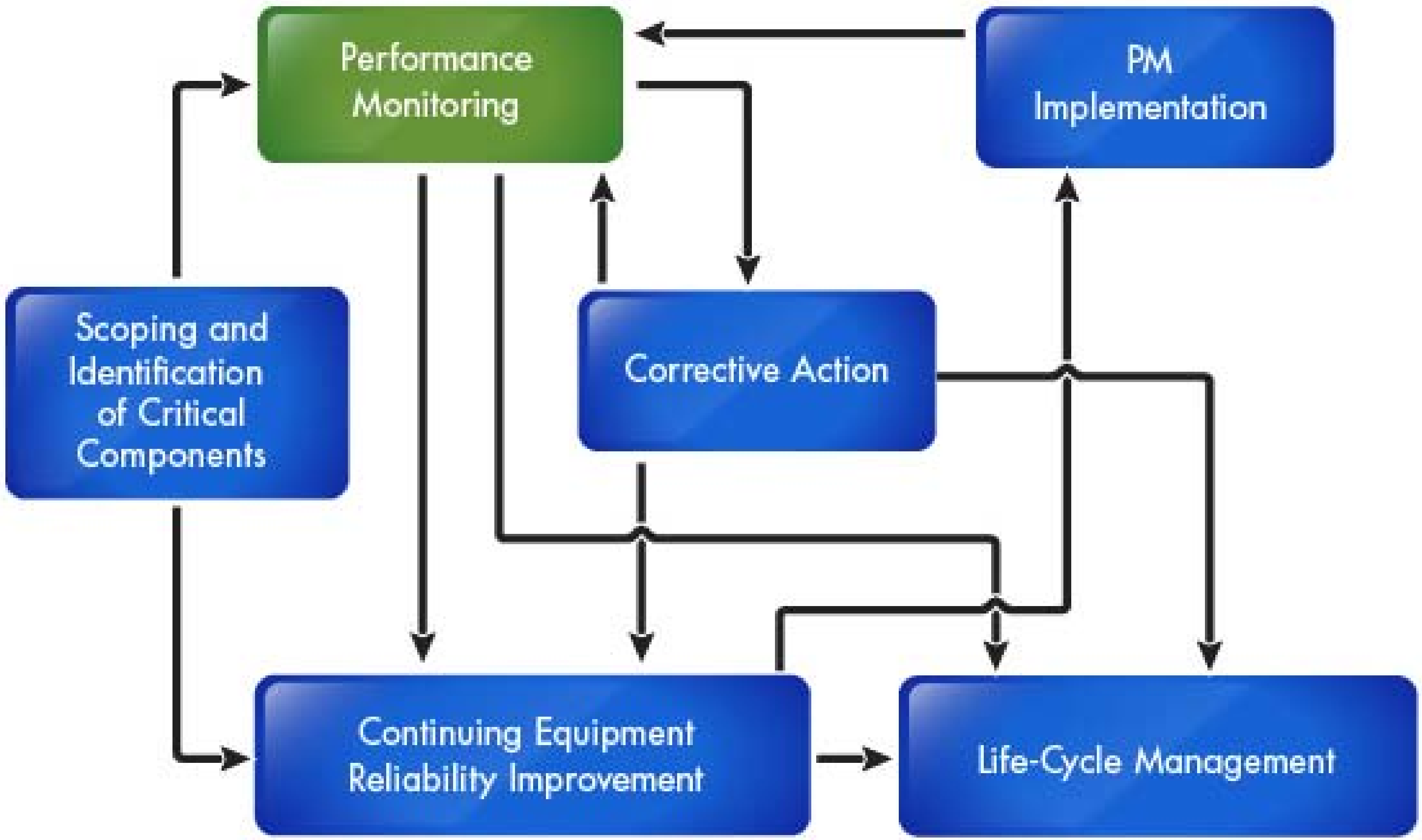
NMAC Services

Maintenance and Engineering Support

- 400+ Component Specific and System Maintenance Guides
  - Technical descriptions, failure modes, preventive maintenance, condition monitoring, troubleshooting, best practices
  - Information is used for maintenance procedures, work planning, etc
- 50+ Process & Strategy Guides
  - Establishing and implementing programs
  - Ex. Preventive maintenance, Foreign material, Clearance and Tagging, Freeze Sealing, On Line Leak Sealing, Outage Management
- Investigation of New Technologies
  - Shaft crack detection
  - Guided Wave Ultrasonics for Gas Void Detection
  - Wire Wheel Alternatives
  - Advanced RCP seals



Equipment Reliability Process: AP-913



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Equipment Reliability Matrix

The Equipment Reliability Matrix is a visual representation of the EPRI materials that are available for each component.

Click the colored cells in the table below to see a list of products for the associated category and component. Green cells indicate that materials are available, yellow cells show that materials are being developed, and gray cells indicate that no materials have been created.

Filter by Component Group

Select a component group from the dropdown list to filter the matrix results.

Component Group: Show All Groups

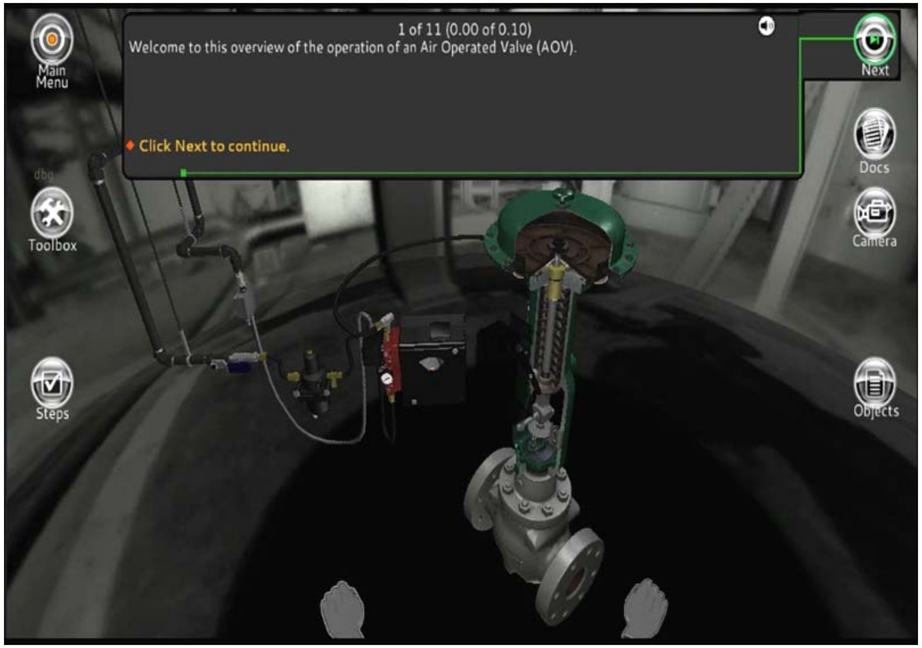
Legend

- Green: EPRI Products Are Available
- Yellow: No EPRI Products Exist But Are Under Development
- Gray: Not Available

	PM Implementation		Performance Monitoring		Corrective Action		Life Cycle Management						Continuous ER Improvement				
	PM Basis	Failure Mechanisms	Monitoring	Testing / Examination	Maintenance Guides	Troubleshooting	Component Replacement Guides	Procurement Repair Specifications	Obsolescence	Aging Management	Source Book	End of Life Guide	Program / Process	Design Application	User Group	Training Offering	Reference Materials
Air	Yellow	Green	Green	Green	Green	Green	Green	Gray	Gray	Green	Green	Gray	Yellow	Green	Gray	Gray	Green
AOV Actuators	Yellow	Green	Green	Green	Green	Green	Gray	Gray	Gray	Gray	Gray	Gray	Green	Green	Gray	Green	Green
Buried Piping	Gray	Green	Green	Green	Green	Green	Gray	Gray	Gray	Green	Green	Green	Green	Green	Green	Green	Green

Air-Operated Valve Ap|

- Getting NMAC Information in the hands of maintenance workers
- Interactive training and field support tool
- More apps under development:
  - Circuit breakers
  - Bolt tensioning
  - AOV diagnostics

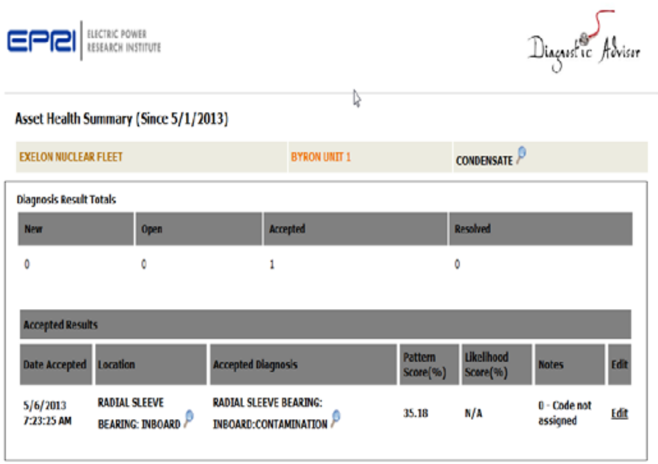


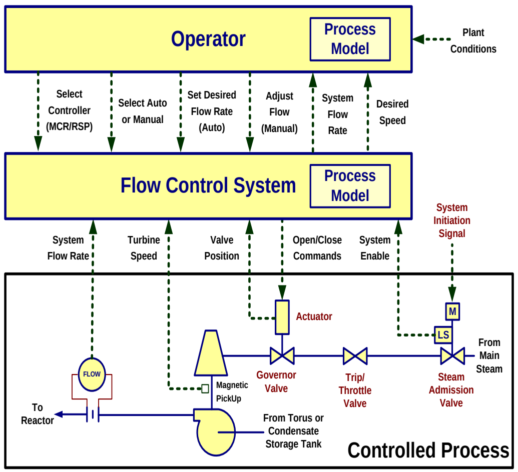
Plant Engineering

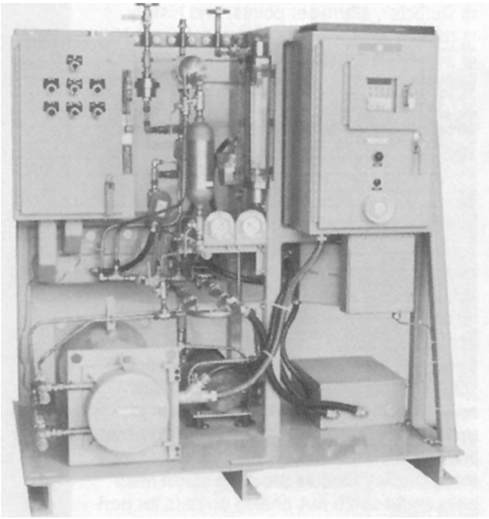
- Life Cycle Management
- Cables aging and degradation
- Buried Piping degradation
- Balance of Plant Corrosion
- Electrical Equipment and Transformers
- Training of Engineers and Technical personnel
- Procurement and Quality
- Engineering Support

Scope & Mission: I&C program overview – 2014 - 2015

Improve plant productivity → ***Replace*** → ***Maintain***







Use I&C technology to improve overall plant health & productivity

Enable implementation of replacement I&C systems

Improve reliability of existing I&C systems and components (e.g., circuit cards)

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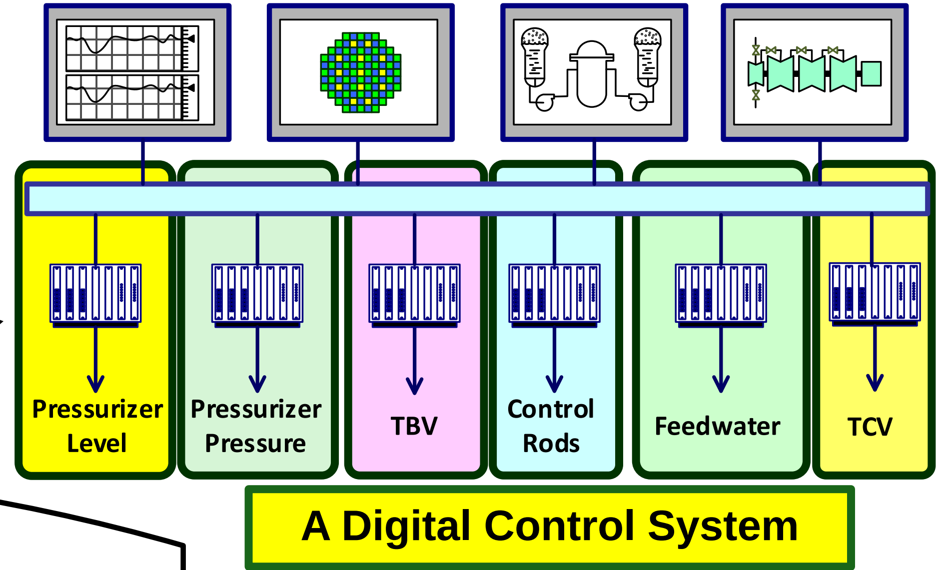
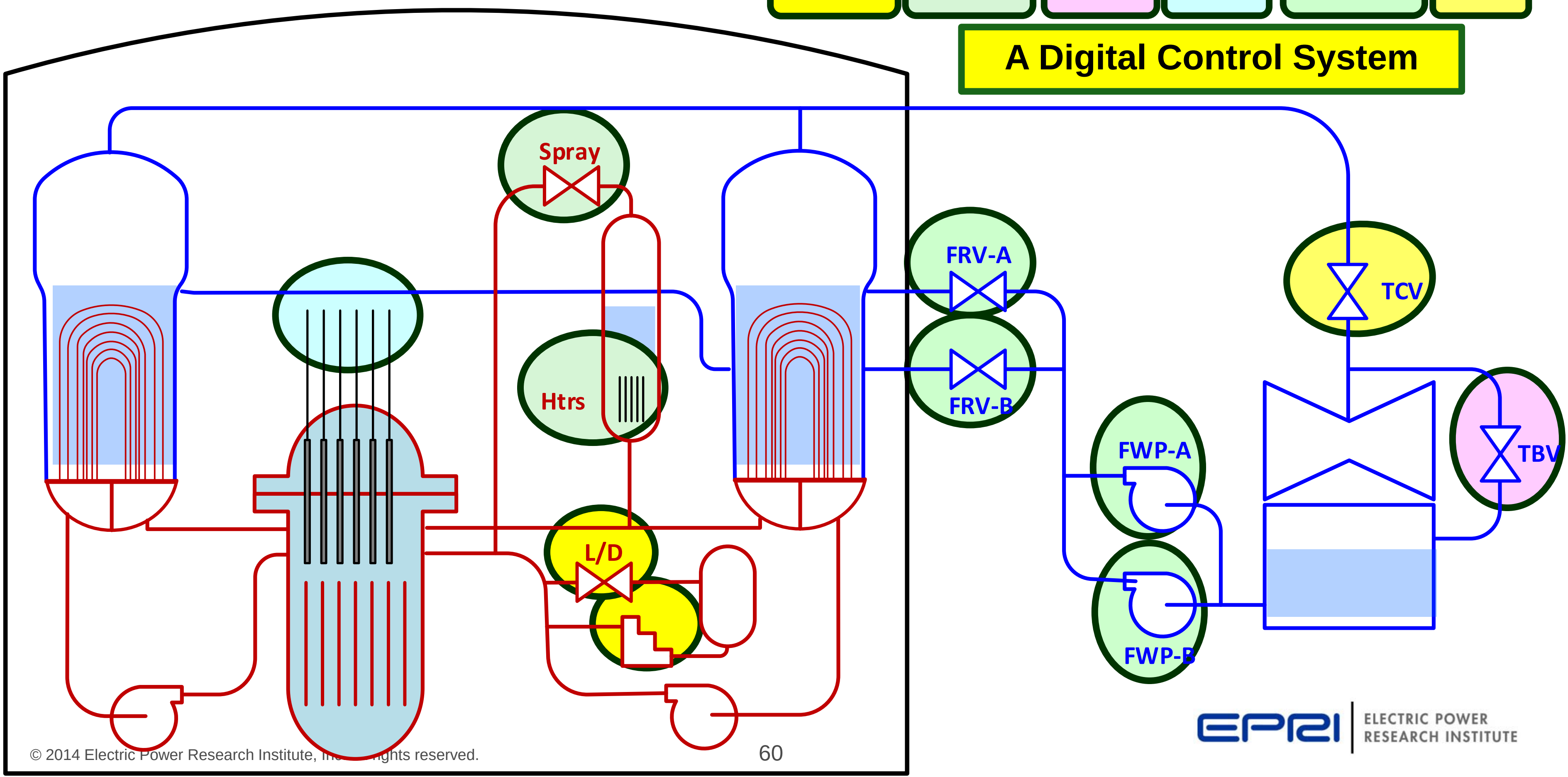
2014 – 2015: Protecting against common-cause failure (CCF)

Note that these are non-safety systems…





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2010+ Value: Cyber Security

Do what is needed to *ensure security* – security <> compliance

IT cyber control technology is not well suited for critical control systems. Blind compliance can have detrimental impacts on nuclear safety and reliability.

Example	Total # of Security Controls	Component	Subset of Security Controls that Apply
Example 1 Single Loop Controller	145	Controller	35
		Configuration Software	65
Example 2 Feedpump Turbine Speed Control Upgrade	135	Governor Positioner	46
		Governor Software Positioner Software	46
Example 3 Digital Feedwater Upgrade	145	Hardware Components	72
		Engineering & Maintenance Workstation with Software	85
		HSI Configuration Data	40

2010 - 2011
- Cyber security design guide, generic procedure & examples
- Training module

2011 - 2014
- Cyber security procurement methodology
- Worked examples
- Training module

2014+
- Procurement packages for cyber with vendors
- EPRI Cyber Security Strategy Development (TI – cross sector)
- Cyber controls applied in the nuclear setting

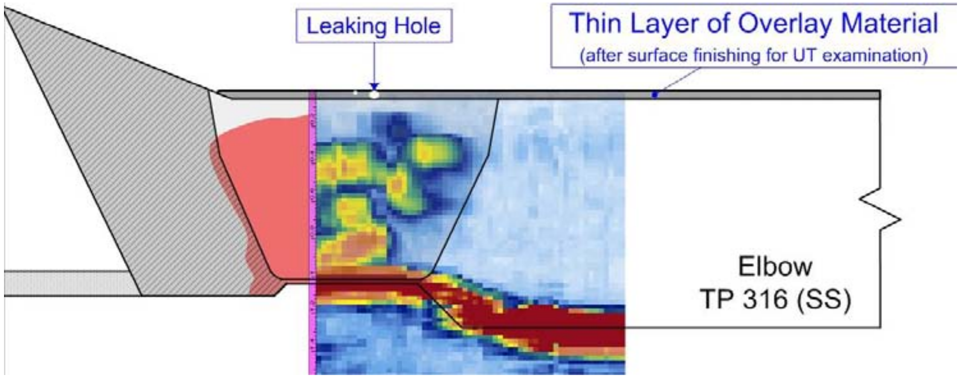
Non-Destructive Evaluation

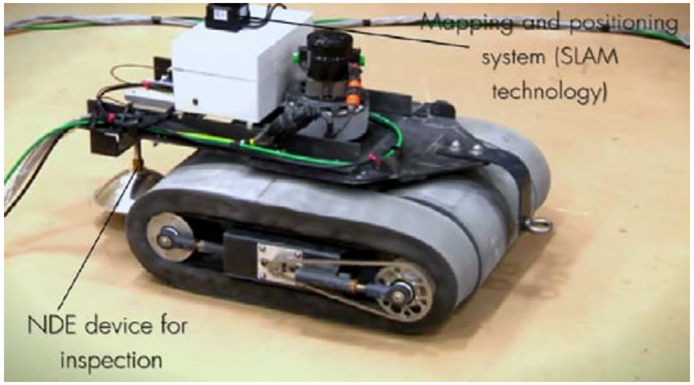
Non Destructive Evaluation (NDE)

- The EPRI NDE Program is an independent NDE resource for the industry
- Large international membership

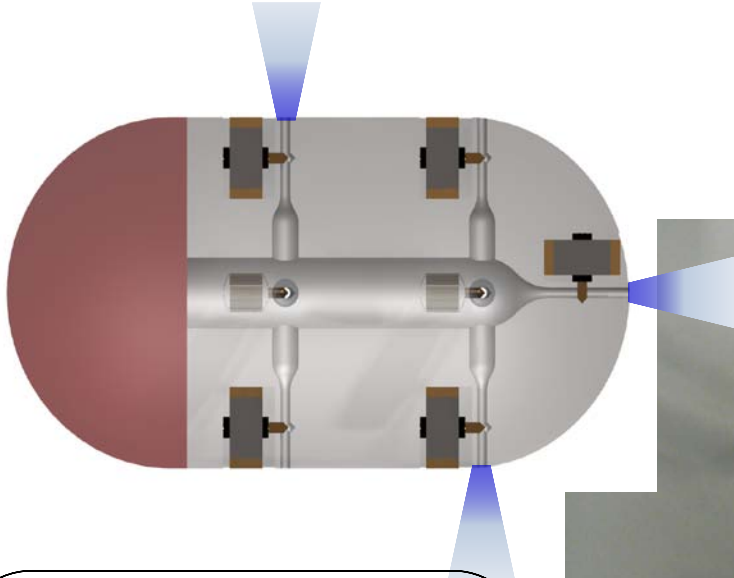
Major areas of R&D activities
- Concrete
- Robotics
- Modeling and simulation
- Spent fuel pools and dry casks
- Fuel

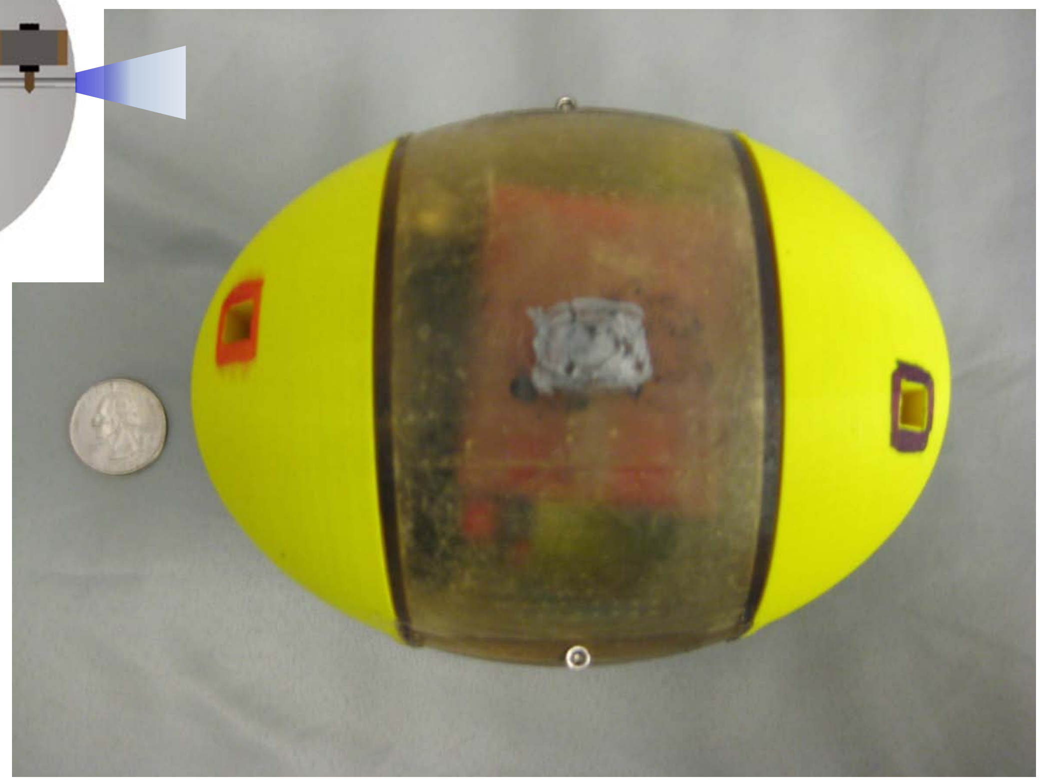
- Performance Demonstration Program





Submersible Robot: Reactor Vessel Internals Inspection





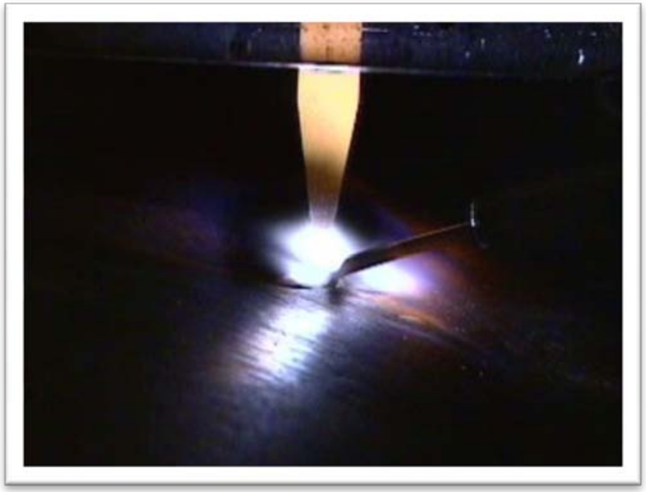
- Collaboration with MIT
- Accurate control
- Submersible
- No Umbilical cord
- Two cameras

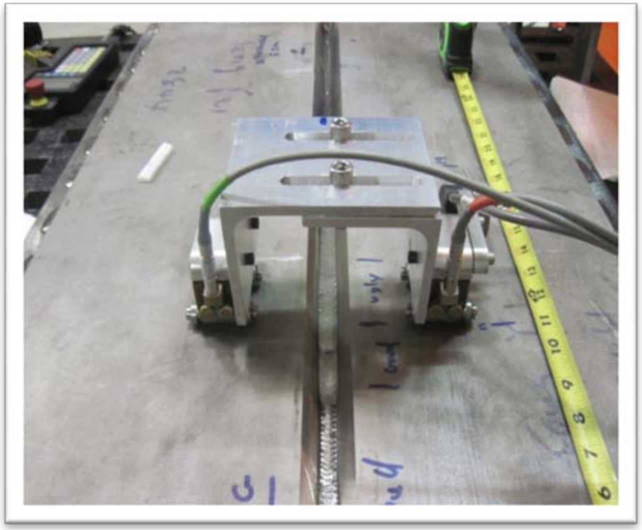
Real-Time NDE of Welds

- Identify defect locations **during** welding
- Adjust process parameters in real time
- Electro-Magnetic Acoustic Transducer (EMAT) technique
  - Inspections without physical contact
  - High-temperature environment

Benefits

- Reduce inspection and repair time
- Reduce residual stress and SCC

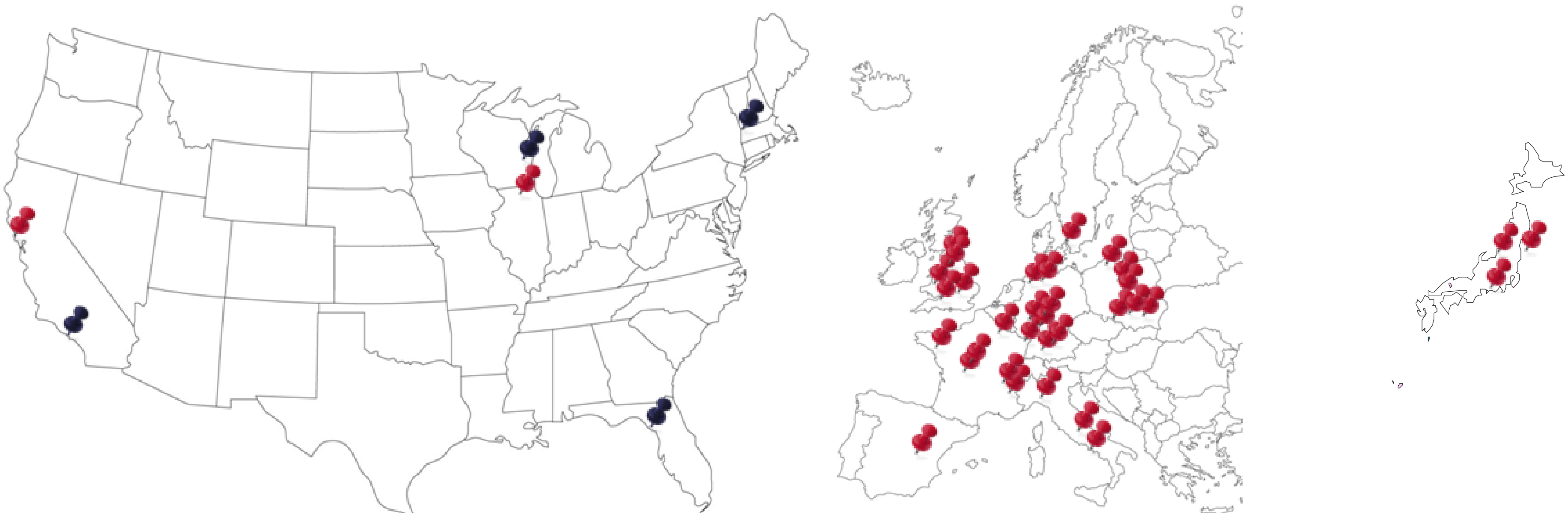




Decommissioning

Active Commercial Nuclear Power Plant Dismantlement Projects

- Dismantlement activities for 46 plants at 35 sites
  - Includes BWR, PWR, VVER, Gas-Cooled and Fast Breeder designs



Plants in transition

Active dismantlement

Additional projects in the planning phase in Asia, Europe and North America

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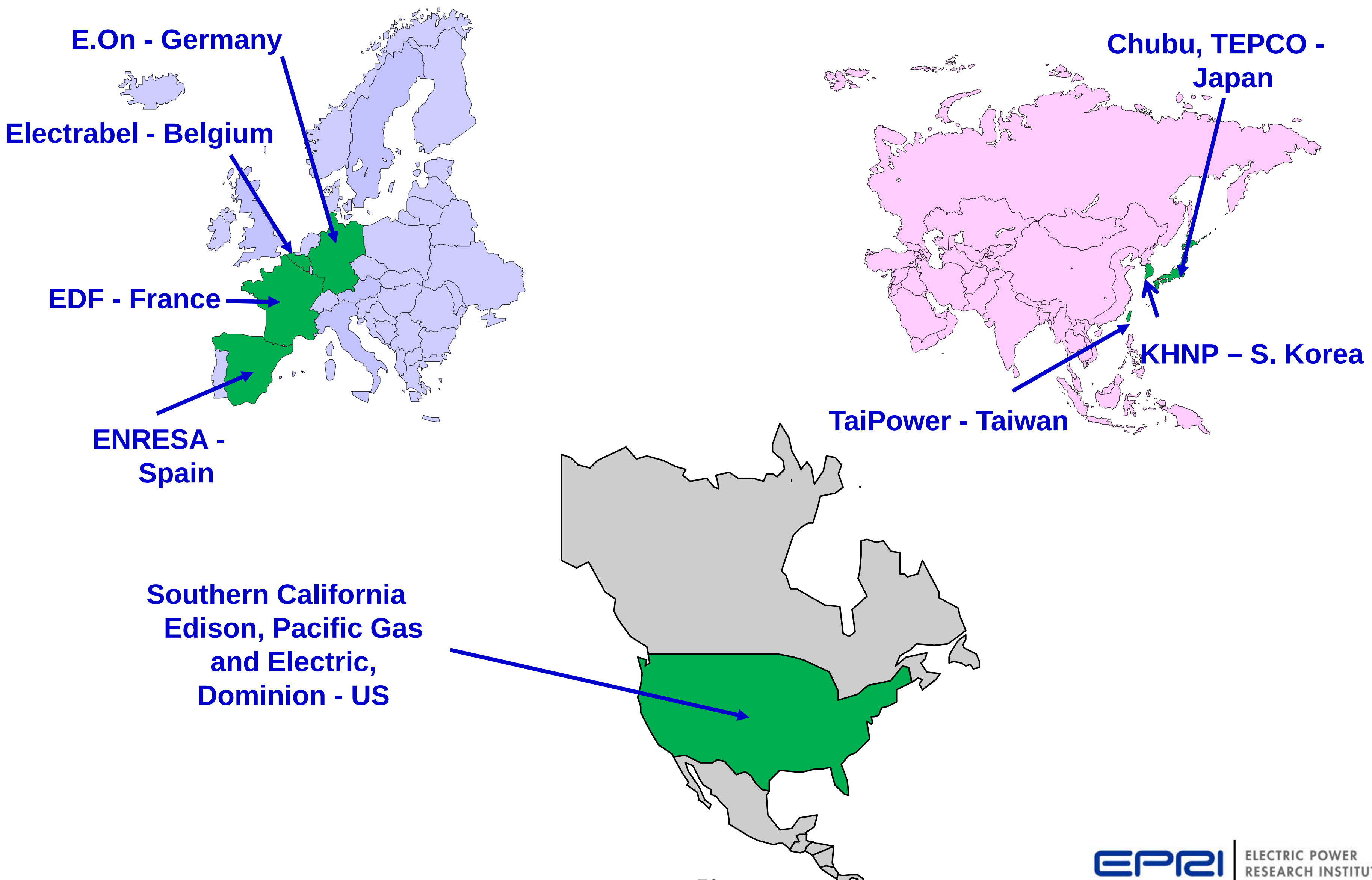
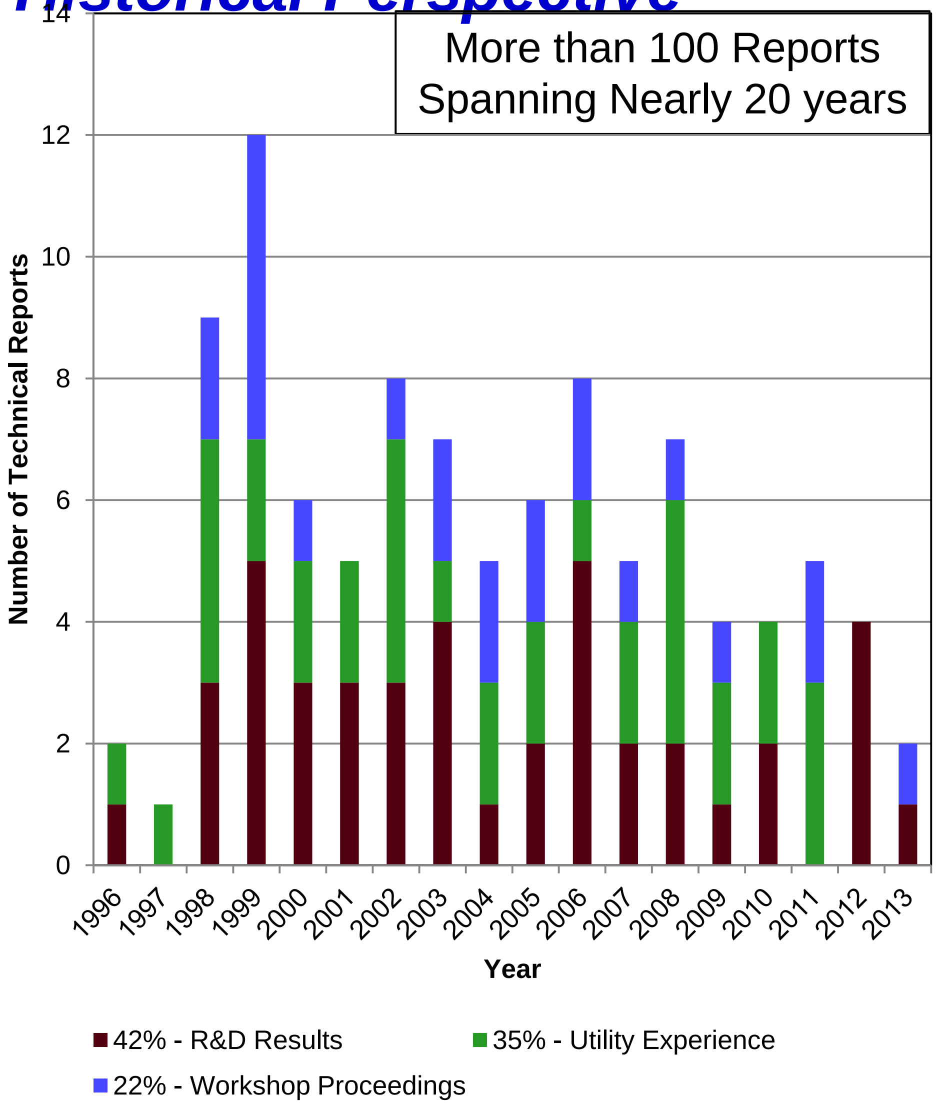
Decommissioning Technology Program Membership



Research & Technology Development (R&D)

Historical Perspective



- Key reports
  - Comprehensive experience summaries
  - Experience summaries on critical activities
  - Dismantlement techniques
  - Guidance on
    - Planning
    - Site characterization
    - Waste management
    - Site assessment and final release surveys

Decommissioning Process

1. Post-Shutdown Transition
2. Fuel to Dry Storage
3. Removal of Highly Radioactive Systems
4. Removal of Remaining Systems
5. Structure Decontamination and Dismantlement
6. Final Remediation and Site Release

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Near-Term Program Research Focus

Technology

- Concrete decontamination
- Hazardous waste management
- Low level waste management
- Graphite removal and disposal
- Metal waste recycling and release
- Applications for automated/robotic equipment

Decommissioning Experience

- Experience outside the U. S.
- Fukushima Dai-ichi

Planning/Regulatory

- Update decision making tools
- Update guidance for regulatory submittals

Coordinate activities with IAEA, OECD, US NRC, US DOE, NEI
And other international industry organizations

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Long Term Operation

Long-Term Operations

Extend value of low-cost, reliable assets

Key Challenges

Develop the technical basis to determine whether

- Life extensions are technically sound
- Benefits of modernization can be justified
- Regulatory issues can be addressed cost-effectively

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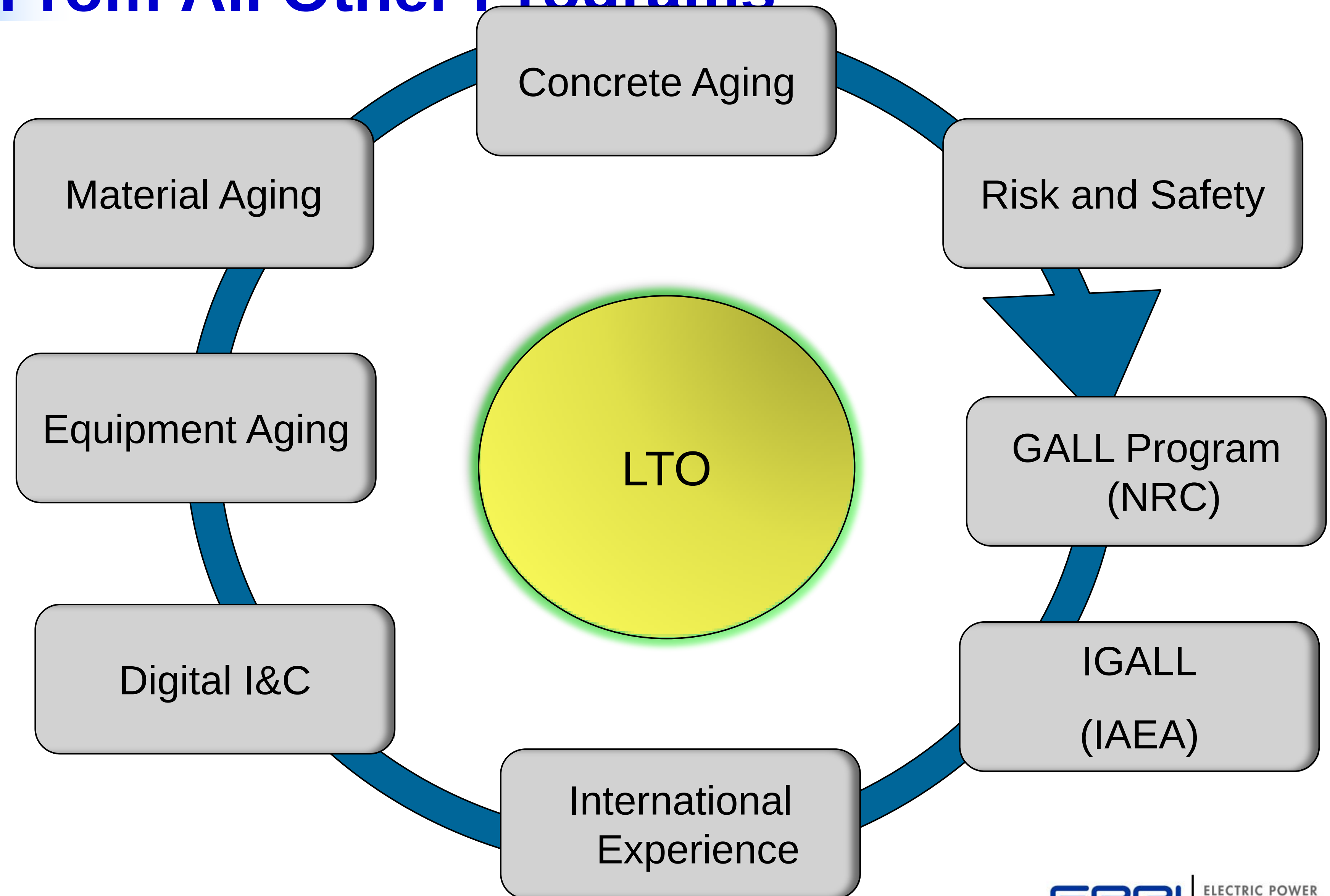
Long Term Operation (LTO) : Drawing From All Other Programs



Conclusions

- EPRI is a global, independent collaborative R&D organization
- Nuclear Sector members own ~80% of the World's fleet
- There is tremendous strength in sharing operating experience, data, expertise and R&D advances
- These insights are channeled back to members through guidelines, software packages, lessons learned and workshops
- As members of EPRI you have access to most of these products and we urge you to take full advantage of them