

# International Collaboration on Materials Research at the NRC

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International Boiling Water Reactor and Pressurized Water  
Reactor Materials Reliability Conference and Exhibition  
The Gaylord National Hotel and Convention Center  
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# Committee on the Safety of Nuclear Installations Activities

**Rob Tregoning, 301-251-7662, robert.tregoning@nrc.gov**



- Objective
  - Assist member countries in maintaining and further developing the scientific and technical knowledge base required to assess the safety of nuclear reactors and fuel cycle facilities.
- Structure
  - Main Committee (B. Sheron, NRC/RES, Chairman)
  - Program Review Group (S. Richards, NRC/RES)
  - Six working groups
    - Working Group on the Integrity of Components and Structures (R. Tregoning, NRC/RES)
    - Metals, concrete, and seismic subgroups
  - Working groups meet yearly to review existing projects, propose new projects, and discuss operational experience
- Participants
  - 21 countries from Europe, Americas, and Asia
  - Regulatory agencies, technical support organizations, industry

# Committee on the Safety of Nuclear Installations Activities

**Rob Tregoning, 301-251-7662, [robert.tregoning@nrc.gov](mailto:robert.tregoning@nrc.gov)**



- Metals-related activities
  - **Leak-before-break (LBB)**
  - **Long-term operations (LTO)**
  - **Component operational experience, degradation and aging program (CODAP)**
  - Benchmark on the analytical evaluation of the fracture mechanics parameters K and J
  - Fatigue of components and structures
  - Probabilistic structural integrity of a PWR reactor pressure vessel (PROSIR)
  - Hydro-proof pressure test requirements
  - Metallic component margins under high seismic loads (MECOS)
- Typical deliverables
  - Databases, state-of-the-art reports, benchmarking and round-robin analytical results, workshops
- Schedule
  - Programs typically last from 1 – 3 years

# CSNI LBB Project

**Rob Tregoning, 301-251-7662, robert.tregoning@nrc.gov**



- Objectives: To identify technical areas of mutual interest related to
  1. Evaluation of structural integrity of piping systems using deterministic and/or probabilistic methods
  2. Demonstration that flaws in piping systems will exhibit leaks prior to failure
- Scope
  - Primary pressure boundary piping
- Participants: Principally regulatory agencies and representatives
  - Belgium, Canada, Germany, Japan, Netherlands, Slovakia, Sweden, Switzerland, United States, waiting on responses from other countries
- Program description
  - Review prior CSNI LBB summary (app. 10 years ago)
  - Develop and conduct a survey to
    - Identify current regulatory and technical requirements used for LBB
    - Identify technical and regulatory concerns related to the aging degradation in LBB systems
  - Identify common issues

# CSNI LBB Project

**Rob Tregoning, 301-251-7662, robert.tregoning@nrc.gov**



- Project status
  - Review of prior LBB studies is complete
  - Initial survey responses have been provided from participants
  - Currently evaluating responses
- Principal deliverables
  - State-of-the-art report (SOAR) summarizing current requirements in each country and identifying technical and regulatory concerns
  - Plan for possible follow-on research addressing common concerns
- Milestone schedule
  - September 2012 – Completion of evaluation of responses
  - December 2012 – Draft of SOAR
  - April 2013 – Final SOAR to CSNI for approval
- Possible follow-on work
  - Develop proposal for follow-on LBB research – December 2012
  - Present proposal for approval – April 2013

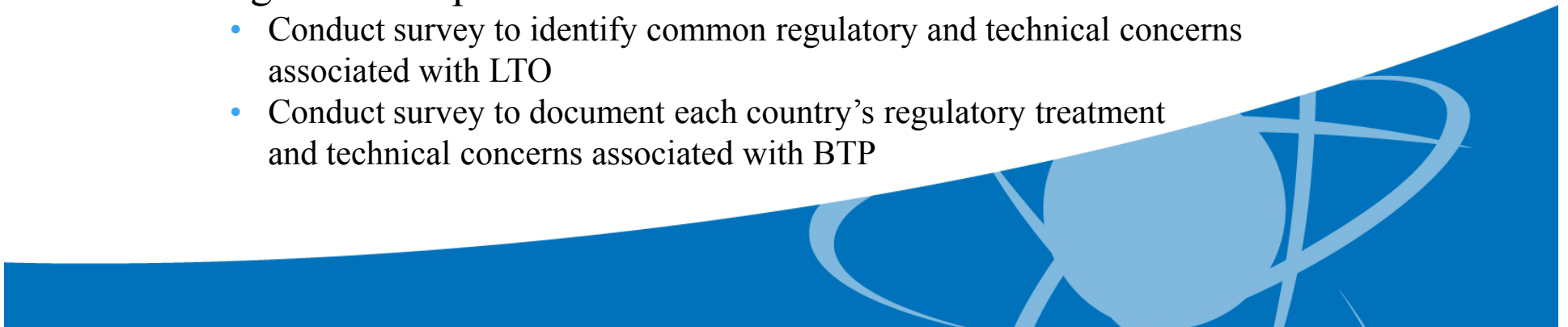


# CSNI LTO Project

**Rob Tregoning, 301-251-7662, robert.tregoning@nrc.gov**



- Objectives
  1. Identify technical areas of mutual interest related to age-related degradation of materials in safety-related systems, structures, components (SSCs) during long-term operation (i.e., > 60 years)
  2. As a trial, capture operating experience and regulatory treatment associated with degradation in buried tanks and piping (BTP)
- Scope
  - Safety significant SSCs; barriers/shields that protect against exposure
  - Metals, concrete, cables, instrumentation and control systems
- Participants: Principally regulatory agencies and representatives
  - Belgium, Canada, Czech Republic, Finland, Germany, Japan, Netherlands, Slovakia, Slovenia, Sweden, Switzerland, United States, waiting on responses from other countries
- Program description
  - Conduct survey to identify common regulatory and technical concerns associated with LTO
  - Conduct survey to document each country's regulatory treatment and technical concerns associated with BTP



# CSNI LTO Project

**Rob Tregoning, 301-251-7662, robert.tregoning@nrc.gov**



- Project status
  - Initial survey responses have been provided from participants
  - Currently evaluating responses
- Principal deliverables
  - SOAR summarizing regulatory treatment and technical concerns in each country associated with BTP
  - Develop plan for follow-on research to address common LTO concerns
  - Evaluate feasibility and need for database of BTP events
- Milestone schedule
  - Sept. 2012 – Complete evaluation of LTO and BTP responses
  - Dec. 2012 – Complete BTP database feasibility study
  - Dec. 2012 – Draft SOAR on BTP
  - April 2013 – Final SOAR on BTP to CSNI for approval
- Possible follow-on work
  - Develop proposal for follow-on LTO research – Dec. 2012
  - Develop proposal for follow-on BTP database – Dec. 2012
  - Present proposals for CSNI approval – April 2013



# CODAP

**Michael Benson, 301-251-7492, michael.benson@nrc.gov**



- Objective
  - Capture international materials degradation events and general knowledge of various degradation mechanisms, in a web-based format
- Scope
  - Degradation of pressure boundary passive components
  - Piping, control rod drive housing, instrumentation tubes, etc.
- Participants
  - OECD/NEA,
  - Regulatory agencies and representatives from United States, Canada, Chinese Taipei, Czech Republic, Finland, Germany, Japan, Korea, Slovak Republic, Spain, Sweden, Switzerland
- Program description
  - Submission of data by participating countries
  - NRC submitting LER data and regulatory history associated with flow-accelerated corrosion (FAC)
  - EPRI participation would greatly enhance the database of US events

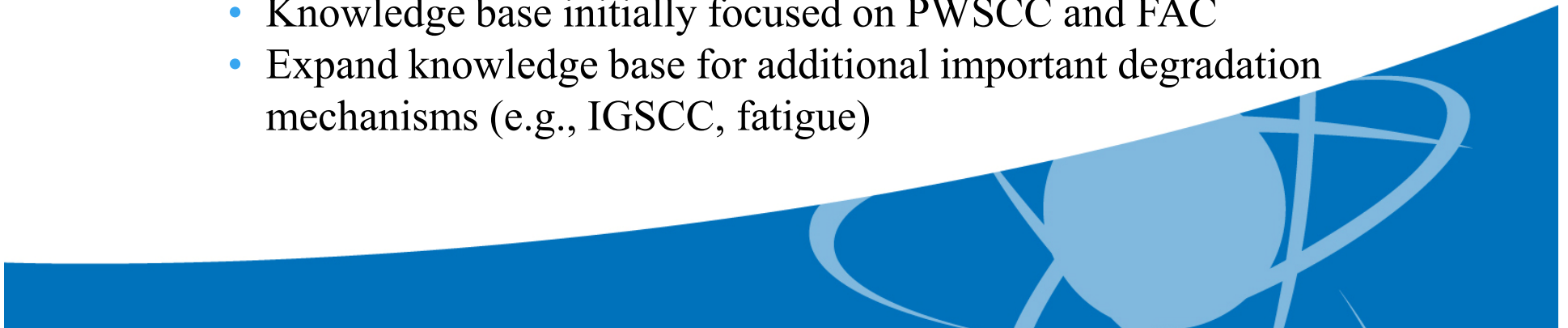


# CODAP

**Michael Benson, 301-251-7492, michael.benson@nrc.gov**



- Status
  - 1<sup>st</sup> year of 3-year agreement
  - Follow-on agreements every 3-years
- Principal deliverables
  - Updated event database
  - Addition of knowledge database for targeted degradation mechanisms
  - Topical reports
- Schedule
  - New web-based format operational – Summer 2012
  - Topical reports – throughout the project
- Future work
  - Knowledge base initially focused on PWSCC and FAC
  - Expand knowledge base for additional important degradation mechanisms (e.g., IGSCC, fatigue)



# International Forum for Reactor Aging Management (IFRAM)

**Gene Carpenter, 301-251-7632, [Gene.Carpenter@nrc.gov](mailto:Gene.Carpenter@nrc.gov)**



- Objective
  - Strengthen regional, and build global, networks to facilitate appropriate exchange of information among those organizations that are presently, or are planning to, addressing issues related to aging management of nuclear power plant systems, structures and components (SSCs)
- Scope
  - Facilitate development, and sharing of, data, information, and best practices
  - Leverage resources to accomplish technical and operational objectives
  - Cooperate in joint research/demonstration projects
- Key participants

Asia	Europe	Americas	<i>Ex Officio</i>
Japan's NISA / Tohoku University Koreas's PRIMA-NET China's Institute of Metal Research	EC's Joint Research Centre Materials Aging Institute NULIFE	US Nuclear Regulatory Commission EPRI US Department of Energy	Secretariat IAEA Nuclear Research Institute Rež

# International Forum for Reactor Aging Management (IFRAM)

**Gene Carpenter, 301-251-7632, [Gene.Carpenter@nrc.gov](mailto:Gene.Carpenter@nrc.gov)**



- Status
  - IFRAM began August 2011
  - Creating a handbook on reactor aging management
- Upcoming deliverables
  - Developing a living quantified listing of
    - Test facilities and their capabilities,
    - Regional subject matter experts
    - Proposed/on-going research by organization
  - Developing and implementing a regional framework to get regulators, industry (utilities & vendors), academia and TSOs to cooperate on the development of data needed for aging management activities
- Future work
  - Identifying and beginning cooperative research in selected technical areas



# Halden Research Program

**Appajosula S. Rao, 301-251-7636, [appajosula.rao@nrc.gov](mailto:appajosula.rao@nrc.gov)**



- Objectives
  - Provide a fundamental understanding of irradiation-assisted stress corrosion cracking (IASCC) and predict the cracking rate in irradiated materials
  - Evaluate irradiation-assisted creep and stress relaxation in-situ
  - Develop new methods to characterize RPV embrittlement
- Scope
  - Aging and performance of reactor vessel internal and RPV materials in LWR environments
- Participants
  - 25 participants (including NRC and EPRI) from Americas, Asia, and Europe
- Program description
  - Use Halden reactor for irradiation of unirradiated and ex-plant materials
  - Conduct in-pile creep and stress relaxation testing
  - Use separate loops for IASCC testing
- Status
  - NRC has been participating in program for the past 10 years.
  - The program is renewed every 3 years
  - Current 3-year program started in Sep. 2011

# Halden Research Program

**Appajosula S. Rao, 301-251-7636, [appajosula.rao@nrc.gov](mailto:appajosula.rao@nrc.gov)**



- Principal deliverables
  - Periodic reports
  - Annual review and planning meeting for materials research
- Schedule
  - Feb. 2012: Proposal review completed by all participating members
  - June 2012: Current program start
  - 2014: Final technical report
- Future work during current program:
  - Assessment of post irradiation heat treatments in ameliorating IASCC susceptibility .
  - Thorough characterization of the irradiated material's microstructure and quantification of the extent of any radiation-induced segregation at the grain boundaries of the materials.
  - Identify candidate replacement materials that exhibit superior creep/stress relaxation properties.
  - Measure irradiation enhanced creep and stress relaxation of replacement materials under different load, temperature, and dose levels.

# Zorita Internals Research Project

**Matthew Hiser, 301-251-7601, [Matthew.Hiser@nrc.gov](mailto:Matthew.Hiser@nrc.gov)**



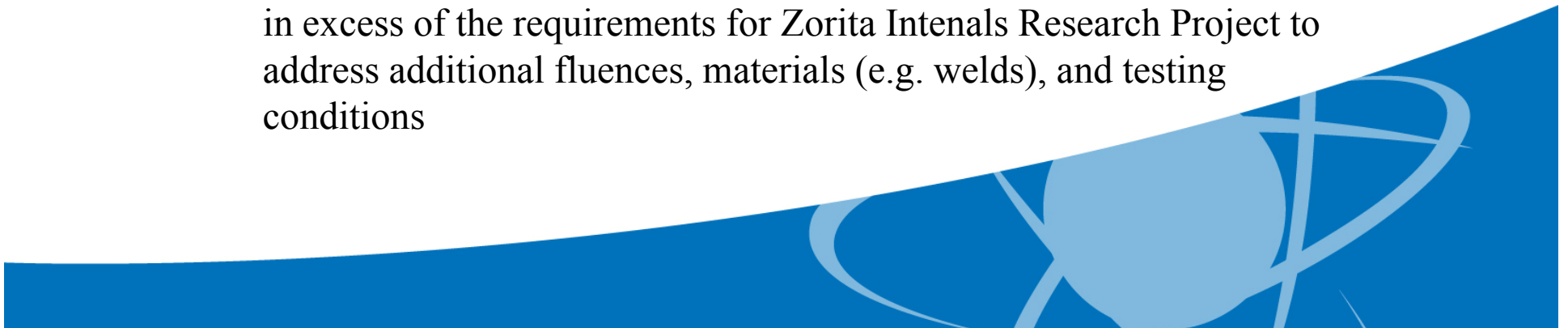
- Objective:
  - Harvest ex-plant materials from a decommissioning Spanish PWR to study the effects of radiation on high-fluence reactor pressure vessel internal materials
- Scope:
  - Reactor vessel internal components exposed to high fluences – baffle and former plates, bolts, core barrel, etc.
- Participants:
  - CSN (Spain), EPRI (US), MHI/Japanese utilities (Japan), NOK (Switzerland), Ringhals (Sweden), Tractebel (Belgium), UNESA/ENRESA (Spain), USNRC
- Program Description:
  - Plate materials will be harvested from the decommissioning plant and tested for IASCC initiation and growth rates, mechanical properties, and microstructural characterization
  - Program management is being provided by EPRI
  - NRC participates as a funding partner and member of the project steering committee

# Zorita Internals Research Project

**Matthew Hiser, 301-251-7601, [Matthew.Hiser@nrc.gov](mailto:Matthew.Hiser@nrc.gov)**



- Status
  - EPRI has contracts in place with SOCOIN to perform temperature/radiation analysis and Studsvik to perform testing
  - The program is moving forward with material harvesting and retrieval in concert with the decommissioning plan
- Principal deliverables
  - Information on IASCC resistance, mechanical properties, and microstructure of materials irradiated under in-service conditions
- Schedule
  - Material retrieval will occur in early to mid 2013
  - Testing completed and final technical report anticipated by 2016
- Future related work
  - NRC and EPRI plan to perform testing on additional material harvested in excess of the requirements for Zorita Internals Research Project to address additional fluences, materials (e.g. welds), and testing conditions



# Weld Residual Stress Finite Element Analysis Validation

Howard J. Rathbun, 301-251-7647, [howard.rathbun@nrc.gov](mailto:howard.rathbun@nrc.gov)



- Objectives
    - Refine weld residual stress (WRS) finite element (FE) model development
    - Determine uncertainty associated with WRS FE results
  - Scope
    - 82/182 DM welds
  - International round robin participants
    - US (Battelle, EMC<sup>2</sup>, ESI Group, Dominion, SIA, Westinghouse), Europe (AREVA, Inspecta Technology), Japan (Institute of Nuclear Safety System, Osaka University), Australia (ANSTO), Canada (Goldak Tech.), UK (Rolls Royce)
  - Program description
    - Double-blind validation using well-controlled mockups characterized with various WRS measurement techniques
    - Four-phase program using flat plate and cylindrical specimens (I), fabricated nozzles (II), and plant components (III and IV)
    - NRC and EPRI worked cooperatively through an MOU
- Addenda

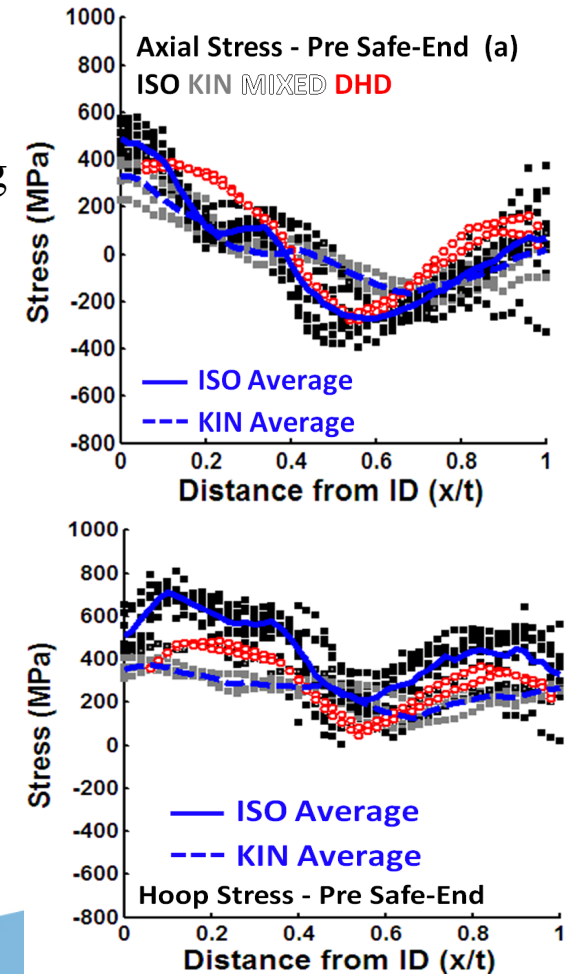


# Weld Residual Stress Finite Element Analysis Validation

Howard J. Rathbun, 301-251-7647, [howard.rathbun@nrc.gov](mailto:howard.rathbun@nrc.gov)



- Status & key results
  - Program is nearing completion
  - Key finding: Significant ( $\sim 200$  MPa) difference among results for weld centerline through-wall stress distributions
- Principal deliverables
  - NUREG report on validating WRS FE models
  - Develop WRS uncertainty distributions for xLPR
  - Recommend review guidance for WRS analyses
- Schedule
  - NUREG complete by Fall 2012
- Future work
  - Welding parameter study
  - Phase 2b nozzle mini round robin
  - Assessment of WRS in repair welds and vessel penetration nozzles
  - Narrow gap welding



# Probabilistic Analysis as a Regulatory Tool for Risk-Informed Decision Guidance (PARTRIDGE)

Raj Iyengar, (301) 251-7907, [raj.iyengar@nrc.gov](mailto:raj.iyengar@nrc.gov)



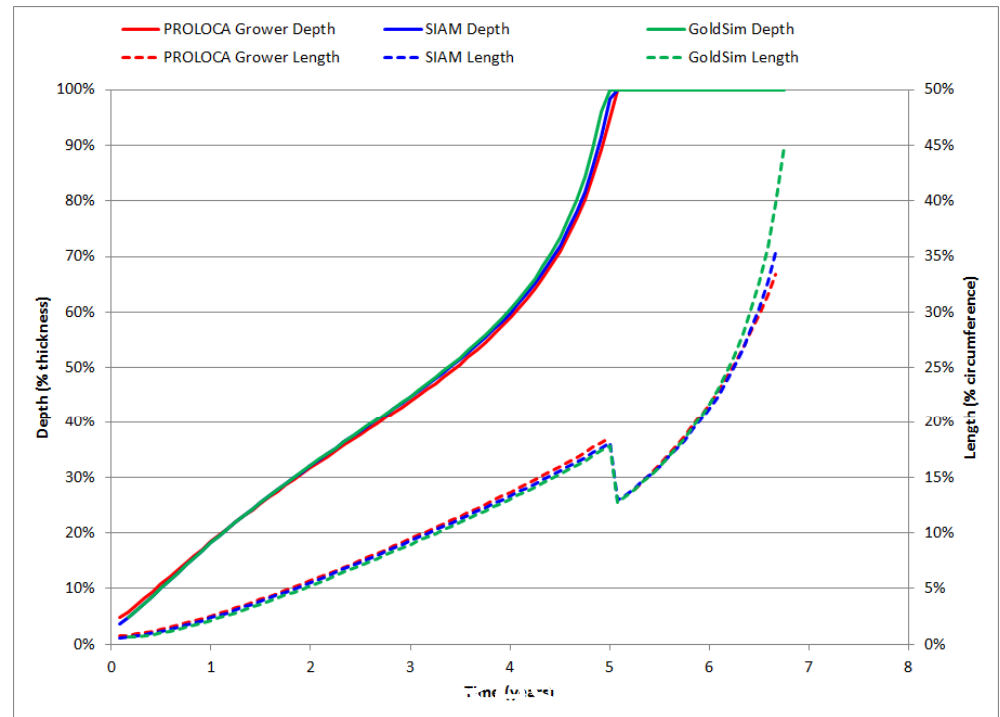
- Objectives
  - Further develop the PRO-LOCA PFM code
  - Support xLPR code development through international participation
- Scope
  - Probabilistic analysis of primary pressure boundary piping systems
- Participants: Continue to solicit international participants
  - Sweden - SSM
  - Canada – CSNA, CANDU Owners Group
  - South Korea – KINS, KHNP, KEPCO
  - Taiwan – INER
  - US – NRC
- Program description
  - Update PRO-LOCA by incorporating latest deterministic models as they become available
  - Test and evaluate PRO-LOCA through sensitivity analyses and benchmarking exercises

# PARTRIDGE

Raj Iyengar, (301) 251-7907, [raj.iyengar@nrc.gov](mailto:raj.iyengar@nrc.gov)



- Status
  - Currently in 2<sup>nd</sup> of 3 year program
  - Released Version 3.0Beta of PRO-LOCA code to Technical Advisory Group (TAG) in April 2012
  - 1<sup>st</sup> TAG meeting in June 2012
- Principal deliverables
  - PRO-LOCA 3.0Beta
  - PRO-LOCA 4.0 (with Adaptive Sampling) – early 2014
  - Final Report – early 2014
- Schedule
  - 2<sup>nd</sup> TAG meeting – late 2013
  - Program completion – summer 2014



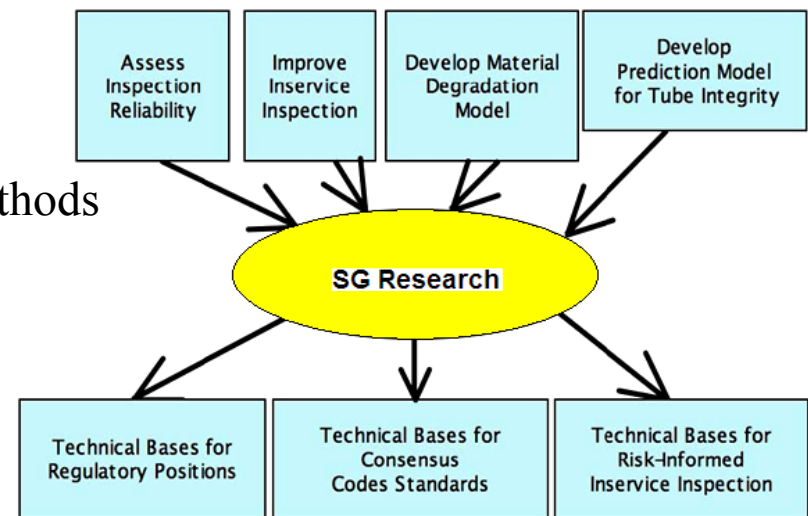
Benchmarking PRO-LOCA 3.0Beta  
Against xLPR Version 1.0

# International Steam Generator Tube Integrity Project

Charles Harris, 301-251-7637, [Charles.Harris@nrc.gov](mailto:Charles.Harris@nrc.gov)



- Objectives
  - Confirm in-service inspection procedures
  - Evaluate SG tube integrity
    - Structures, corrosion, FEA prediction
- Scope
  - Steam generator tubes and inspection methods
- Participants
  - Canada – CNSC, AECL
  - France – IRSN, CEA
  - Korea – KINS, KAERI
  - Japan - JNES
  - USA – EPRI, NRC, ANL
- Program description
  - Participants evaluate materials and eddy current inspection methods
  - Information and resources are shared between nations

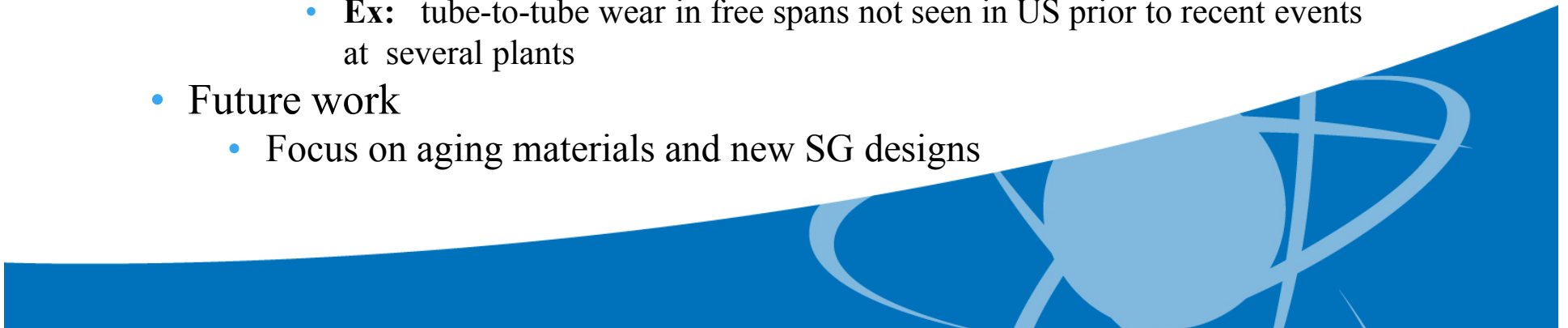


# International Steam Generator Tube Integrity Project

Charles Harris, 301-251-7637, [Charles.Harris@nrc.gov](mailto:Charles.Harris@nrc.gov)



- Status
  - More than 20 years of international cooperation
  - Currently in fifth 5-year term
- Upcoming deliverables
  - NUREG/CR, “Development and Validation of Models for Predicting leakage from Degraded Tube-to-Tubesheet Joints During Severe Accidents” {i.e. the “Severe Accident Report”}
    - Supported NRR review of “H\*” analysis to reduce inspections within tubesheets.
  - NUREG/CR, “Evaluation of Industry Methods of Automated Analyses of Eddy Current Signals in SG Tubes”
    - Support evaluation of recent forms of degradation which would not necessarily be captured by computerized inspection systems
    - **Ex:** tube-to-tube wear in free spans not seen in US prior to recent events at several plants
- Future work
  - Focus on aging materials and new SG designs



# PARENT Program

**Iouri Prokofiev, 301-251-7655, [Iouri.Prokofiev@nrc.gov](mailto:Iouri.Prokofiev@nrc.gov)**



- Objectives
  - Evaluate the ability of eleven different NDE techniques to detect and characterize PWSCC in nickel alloy components and welds
  - Evaluate the effectiveness of open and blind inspections using 22 test teams
- Scope
  - Ten large bore dissimilar metal welds: ~80-90 cm diameter
  - Ten small bore dissimilar metal welds ~10-40 cm diameter
  - Nine bottom mounted instrumentation penetrations
- Key participants:
  - US NRC and PNNL in partnership with EPRI, SIA and IHI - Southwest Technologies
  - Organizations from Japan (JNES, JPEIC, Tohoku University, MHI, KEPCO), Korea (KINS, KAERI, Doosan, KHNP, KPS, Sungkyunkwan University), Sweden (SSM, SQC), Finland (VTT, Aalto University), Switzerland (ENSI, PSI, and SVTI)



# PARENT Program

**Iouri Prokofiev, 301-251-7655, [Iouri.Prokofiev@nrc.gov](mailto:Iouri.Prokofiev@nrc.gov)**



- Program Description
  - Evaluate commercially-used inspection techniques using blind round robin testing (RRT)
    - How effective are qualified inspectors and procedures?
    - Which techniques are the most effective for different components?
  - Evaluate emerging NDE techniques using open RRT
    - Can small flaws be found using novel techniques?
    - Which new techniques show the most promise?
- Principal deliverables:
  - Two NUREG/CR reports with open and blind RRT results
  - Atlas Information Technology Tool (2015)
- Schedule:
  - Conduct open RRT: January 2012 – November 2013
  - Perform blind RRT on six Japanese test blocks: October 2011 – October 2012
  - Conduct blind RRT: March 2012 – October 2014
- Future work
  - Transfer Atlas to NRR & Regions

