Description of AREVA NP Inc.

Pedro Salas
Director, Regulatory Affairs

Lynchburg, VA.
June 12-14, 2012

AREVA

Agenda – June 12, 2012

- ***11:00 Welcome and Introductions – Salas/Curca-Tivig***
- ***11:10 Description of AREVA NP Inc. – Salas***
- ***11:30 AREVA Global Dimensions for Codes and Methods Development – Curca-Tivig***
- ***12:00 Lunch***
- ***12:30 Topical Report Submittals – Salas***
- ***1:30 Methods Issues 2012 Update - Kliewer***
- ***Thermal Conductivity Letter Update***
  - ***2:00 BWR - Pruitt***
  - ***3:00 Thermal-Mechanical - Mohan***
  - ***3:30 LOCA – Uyeda/Klingenfus***
  - ***4:00 Non-LOCA - Higar***
- ***5:00 Adjourn***

Agenda – June 13, 2012

- *8:30 U.S. PWR Fuel Product Update – O'Brian*
- *9:30 PWR Core Engineering Methods - Segard*
- *11:00 BWR Fuel Design Update - Garner*
- *12:00 Lunch*
- *12:30 BWR Codes and Methods Development - Pruitt*
- *2:30 PWR Operating Experience - Strumpell*
- *3:30 PWR Mechanical Faulted (Seismic and LOCA) Analysis Methodology - Matthews*
- *5:00 Adjourn*

Agenda – June 14, 2012

- *8:30 BWR Fuel Performance Update - Garner*
- *9:30 AREVA Burnup Extension Program - Bellanger*
- *10:00 NRC Rulemaking – Clifford*
- *11:00 LOCA 50.46 Process – Elliott/Uyeda*
- *12:00 Lunch*
- *12:30 PWR Fuel Assembly Distortion – Gardner*
- *1:30 Closing Remarks*
- *2:00 Adjourn*

Safety Message

Objectives

Objectives

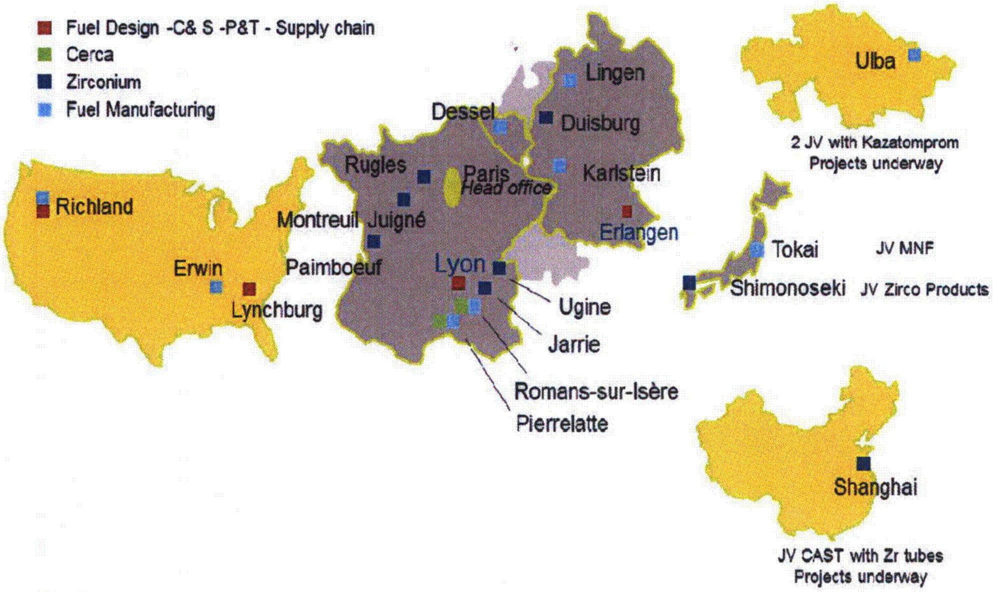
- **Outline of discussion**
  - Program issues
  - TCD letter update
  - Fuel designs
  - Core engineering methods
  - Operating experience
  - Fuel exams
  - Observations and solutions

- **Objectives**
  - Increase NRC understanding of AREVA's fuel designs and methods
  - Exchanging ideas and expectations on fuel issues
  - Open communication; ask questions

AREVA U.S. Fuel Business Unit

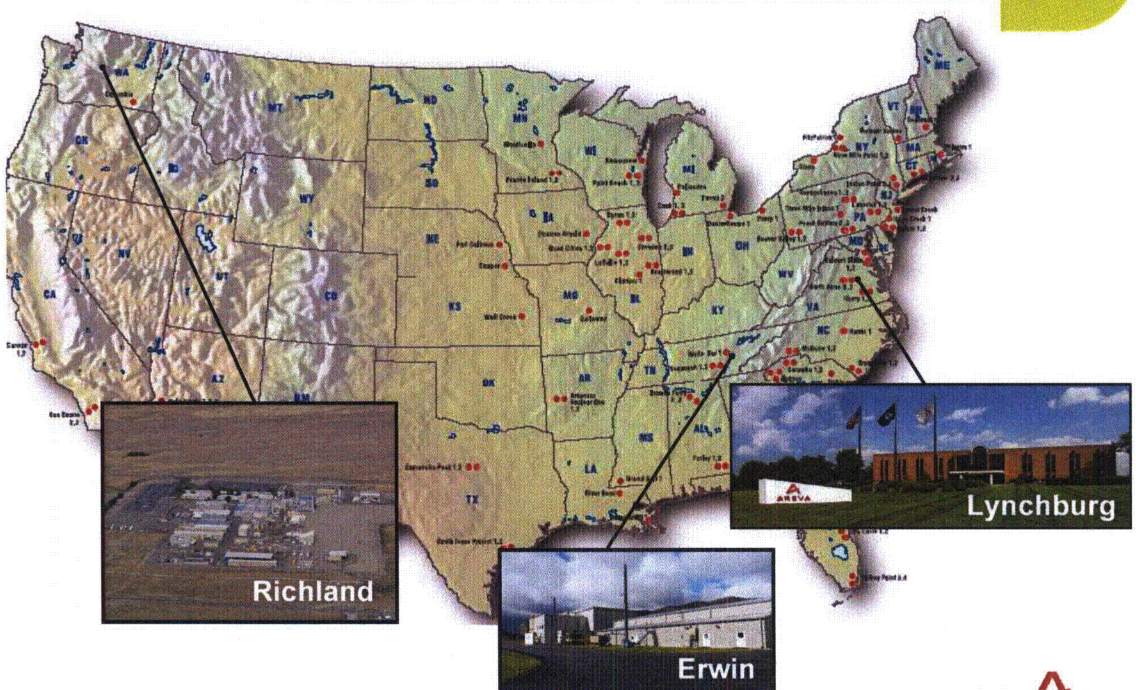
AREVA

AREVA FUEL ACTIVITIES



A Worldwide Expertise Serving the Utilities

AREVA U.S. Fuel Facilities



Richland Fuel Fabrication Facility

1971
Facility Constructed

Since 1990
- 298 Powder Shipments
- 430 Pellet Shipments

2007
1,000,000 ATRIUM ™ Fuel Rods

50,000 Fuel Assemblies Shipped (as of 5/31/2012)

Richland Fuel Fabrication Facility

Facility Size

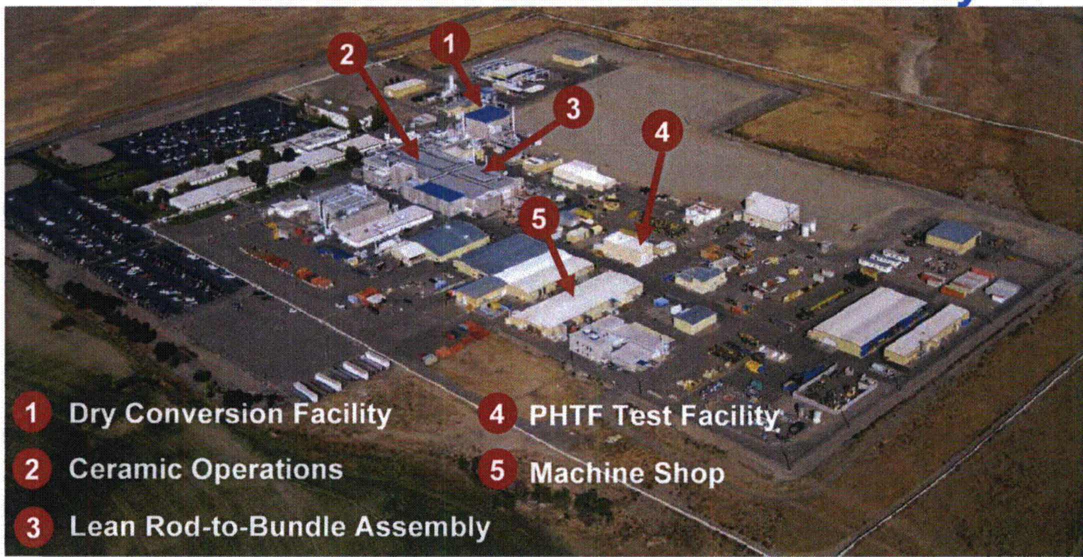
404,000 Square feet

Avg. Yrs Experience = 15

Laboratories = Analytical & Materials

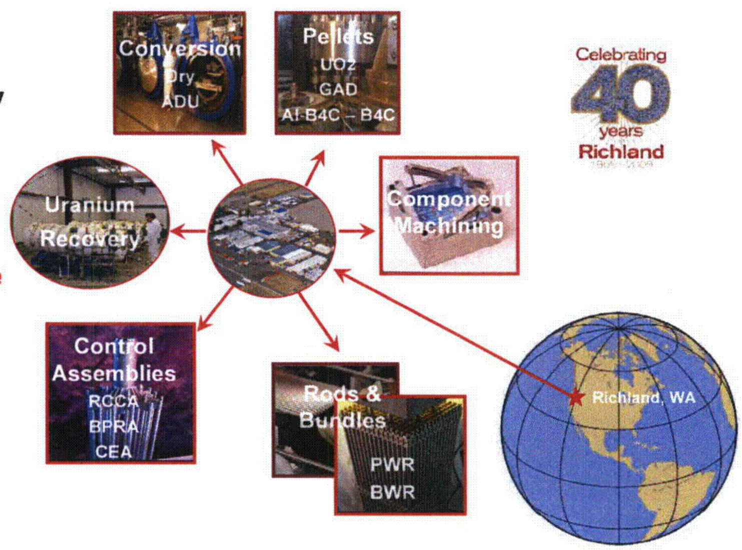
Testing Facilities = Advanced Fuel Design

Achieving Fuel Fabrication Excellence
Richland Fuel Fabrication Facility



Achieving Fuel Fabrication Excellence

- **Integrated, flexible and state of the art fuel fabrication facility**
  - **From UF6 to final fuel assembly**
  - **Lean manufacturing set-up : product /data workflow , product line change over**
  - **Best practice fuel manufacturing technology**
  - **First US fuel site to receive 40 year plant license renewal**



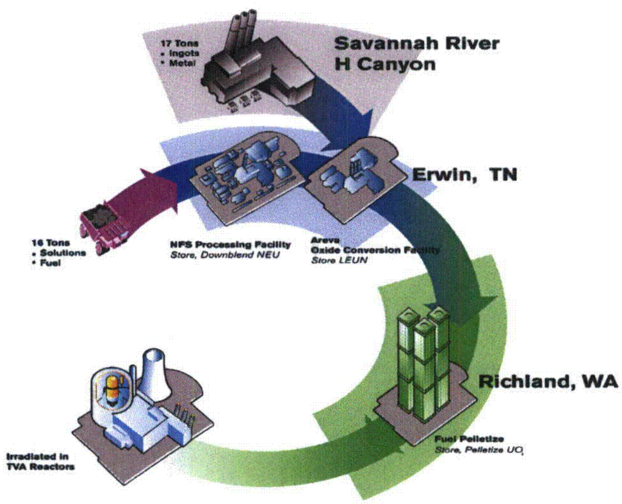
Richland is AREVA Center of Excellence for Fuel Manufacturing in the US

Achieving Fuel Fabrication Excellence

- **Our safety culture**
  - Providing a safe work environment for our workforce
  - Safety culture drives overall culture of excellence
- **Global best practices**
  - Conversion, Ceramics, Rod and Bundle, Component Manufacturing
  - Over $65M capital investments in the last decade
- **Flexible fuel fabrication plant**
  - Provide the full spectrum of products our customers need
  - Proven record of flexibility to meet Customers' needs
  - Providing high quality products, efficiently and cost-effectively
- **Our people**
  - Ensure the right people are in the right jobs doing the right things
  - Rigor – Ownership - Pride

»» ***Global resources ensure state-of-the-art fuel is designed and fabricated with the highest quality***

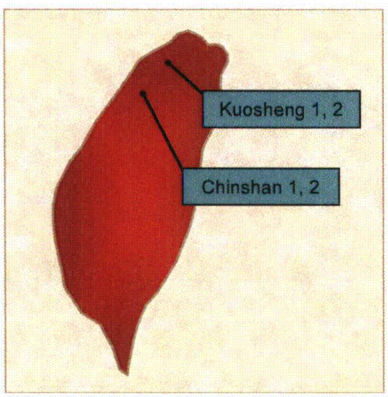
Operations
BLEU Conversion Complex



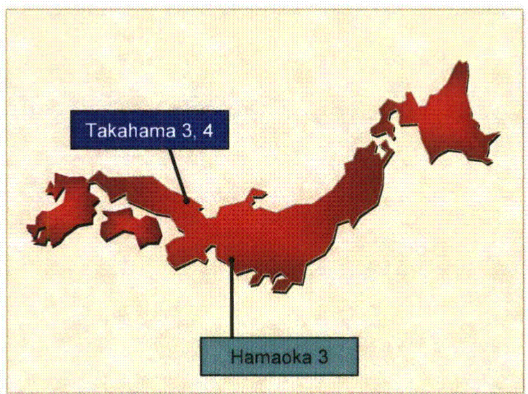
AREVA U.S. Fuel Customers

North Anna-2 Last Delivery Spring 2011
Songs 2 – Delivered Dec. 2011 / Songs 3 Delivery Early 2013
Browns Ferry 1 – Delivery 2012
St. Lucie 2 – Delivery 2017

Taiwan and Japan Fuel Customers



Taiwan



Japan

BWR

PWR

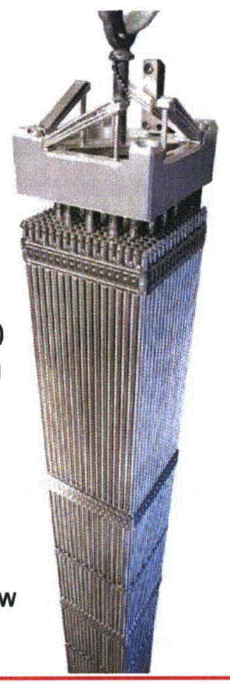
Fuel Assemblies - Types

General Electric BWR	Combustion Engineering PWR	Babcock & Wilcox PWR	Westinghouse PWR
BWR 9x9	CE 14x14 HTP	Mark-B 15x15	W15x15 HTP
ATRIUM™ 10	CE15x15 HTP		W17x17 HTP W17x17 Adv HTP
ATRIUM 10 XM	CE16x16 HTP		Mark-BW 17x17

Fuel Assemblies – Plant Designs

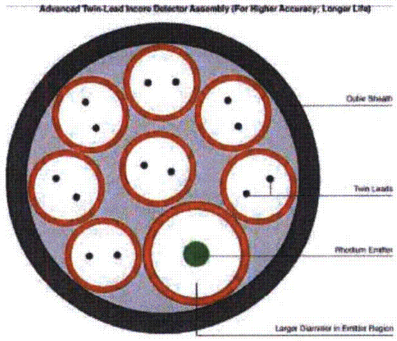

ATRIUM™ 10XM

- Boiling water reactor (BWR) fuel – Plant Designs
  - GE
  - Siemens
  - ASEA
- Pressurized water reactor (PWR) fuel – Plant Designs
  - Babcock & Wilcox (B&W)
  - Combustion Engineering (C-E)
  - Westinghouse (W)
  - Siemens
  - AREVA NP

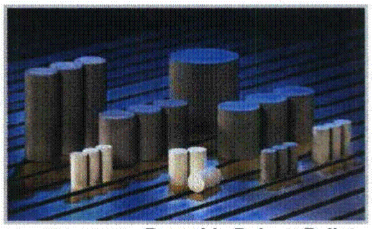

Advanced Mark-BW

Fuel-Related Components

Components	B&W	C-E	W
Control Components	√	√	√
Burnable Poison Rod Assemblies	√	√	√
Incore Detectors	√	√	√
Flux thimble thermocouple			√

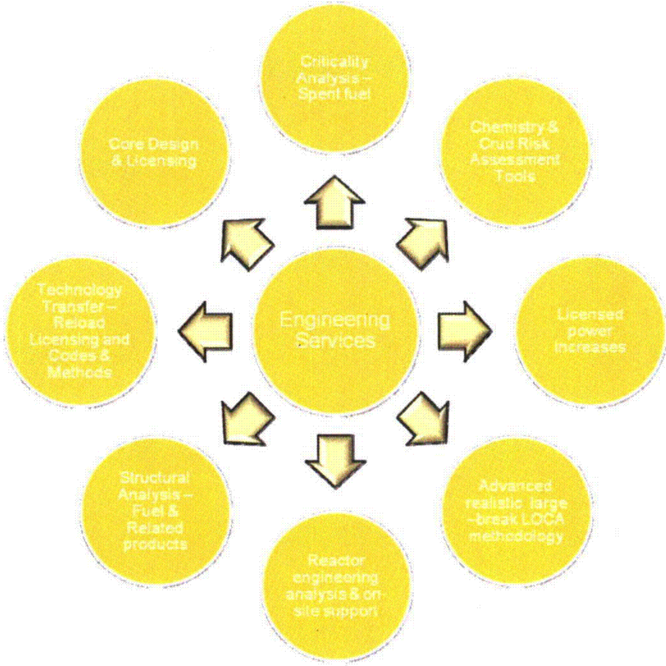


Incore Detector


Burnable Poison Pellets

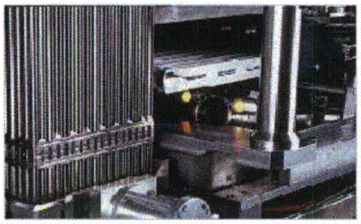

BPRAs

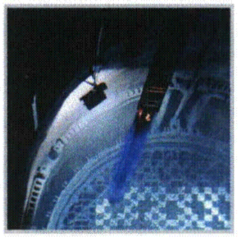
Engineering Services

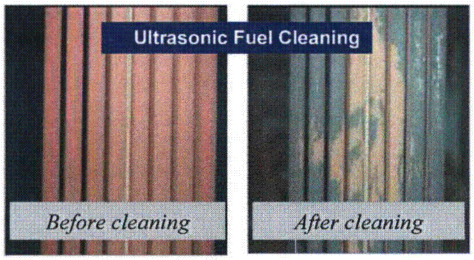


Fuel Services

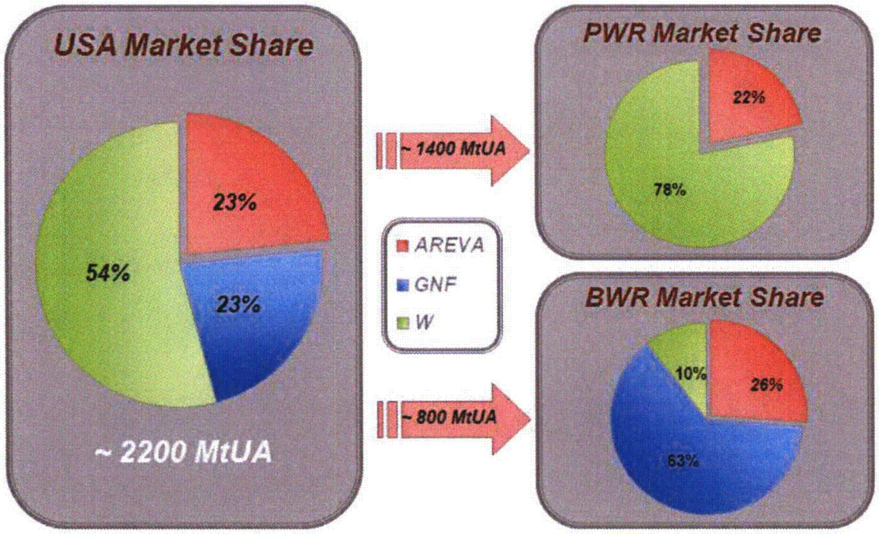
- Fuel Inspections
  - Ultrasound
  - Eddy Current
  - Fuel Sipping
- Fuel Cleaning
- Fuel Repair & Reconstitution
- Specialty Tooling







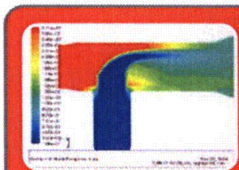
Market Trend Analysis
Market Share



AREVA U.S. Installed Base Business Units

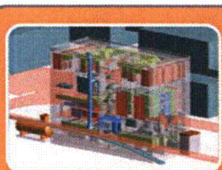
AREVA

Installed Base Business Units



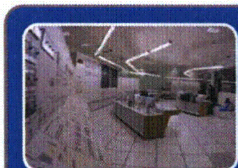
Plant Studies

- Basic Engineering activities, Licensing & Safety related studies



Plant Upgrades

- Modernizations, Power Uprates, Life Time Extensions
- Completion Projects (e.g. Angra 3, Bellefonte)



I&C / Electrical Systems Modernization

- Safety and Reactor I&C Systems (TELEPERM XS), Non-Safety I&C, Electrical Systems (Power Supply & Distribution, Variable Frequency Drives), I&C/ES Engineering Services

Installed Base Business Units

Outage Services

- Refueling and Maintenance Services, P&M Services, Chemistry & Decontamination, Diagnostic & Monitoring
- Our teams are involved in more than 110 Outages every year around the Globe
- Outage Control Center – overall focus of outage synergies

Non-Destructive Examinations Solutions

- Pre- and In-Service Inspection, for nuclear & industrial niche markets
- Leader in NDE for PWR, BWR and VVER
- NDE Technical Center for base R&D serving all AREVA units

Component Repair & Replacement

- Repair and replacement of primary circuit components
- 53 SGRs, 90 RVHRs and 2 Pressurizer Replacement operations in the world (End of 2009). On the shelf and skilled repair and mitigation processes for all parts of the NSSS, adapted to all plant designs and national regulations

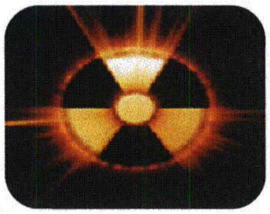
Achieving Operational Excellence Commitment to Health & Safety

Safety

- Our people view personnel and nuclear safety as an intrinsic core value
- AREVA uses utility specific health - Safety Plan
- We measure effective performance
- Safety conscious work environment

ALARA

- **2 REM limit per person annually (rolling)**
- **Reduction in radiation exposure is a top priority for AREVA**
- **Equipment designed for dose savings**



Human Performance

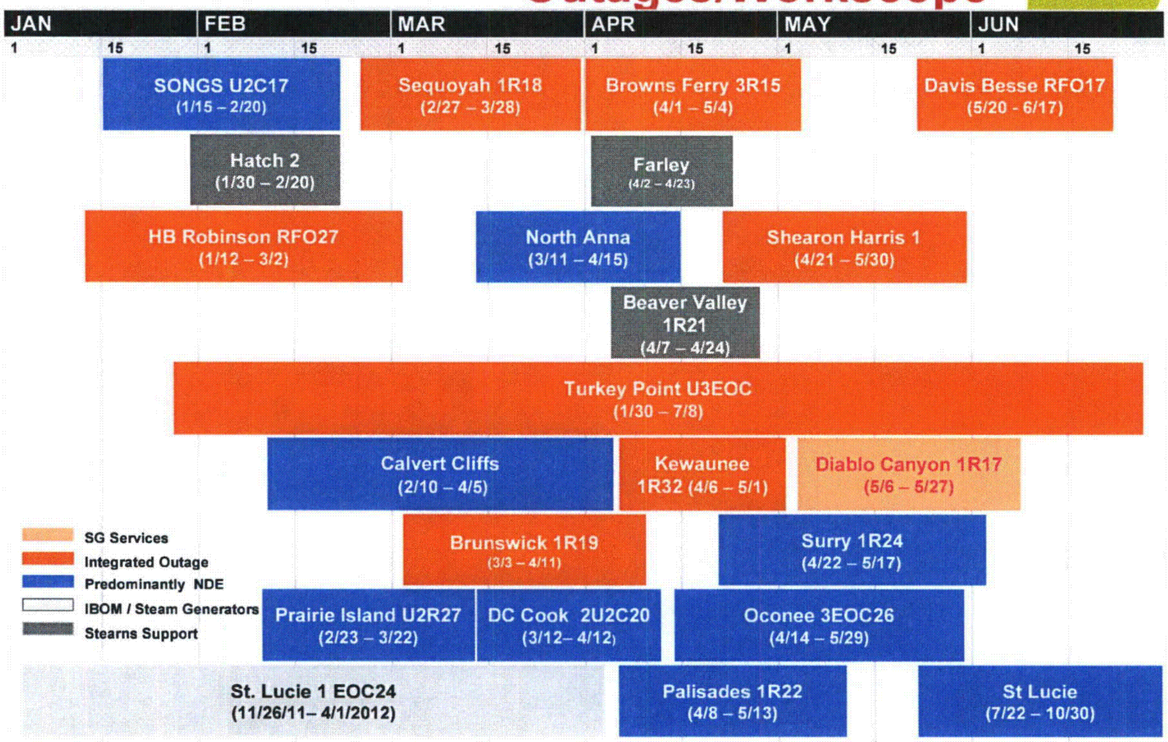
- **Observation brief from previous day with specific focus area for the day**
- **Assessments performed for trends / focus areas**
- **CRs generated for each product line for review and action**

Outage Work

- AREVA supported 26 outages during the Spring 2012 season which still continues through July 1
- Manhours in field is > 1,000,000 with no OSHA Recordables or TISAs to date
  - AREVA Reactors & Services has recently received its second consecutive Performance Award for Safety
- > 85% of AREVA's work is on critical path for outages
  - Refuel Services
  - Steam Generator Services
  - Weld Repairs
  - RVCH Inspections
  - MRP Vessel Inspections
  - Fuel Equipment Support & Modifications

Supporting greater than 50 outages per year!

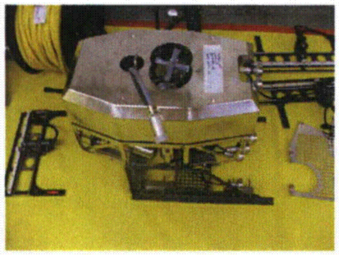
Spring 2012 Outages/Workscope



Equipment FME Prevention Improvements

AREVA initiated a CR to drive improved performance

- Created "Clean Zone" for FME inspections at SERF 4
- Pre-job brief with photos
- Capture good and bad practice on camera
- Improved FME Awareness Lesson Plan
- Revised current procedures
- QA oversight with documentation
- Prohibit the use of tape
- Measuring performance improvements



Striving for Top Decile to Meet Industry Needs

AREVA Resource Development Strategy

Developing Tomorrows Workforce Today - Ensuring a Pipeline of Resources Far into the Future

AREVA Global Dimensions for Codes & Methods Development

Florin CURCA-TIVIG
Global Manager C&M Strategy and Development
Global Fuel Safety Manager

AREVA

Executive Summary

- AREVA started implementing a new generation of advanced Codes & Methods integrating state of the art physics
- The new methods can accommodate changing regulatory requirements and customer needs worldwide
- AREVA C&M development is unique by its global dimensions
  - All regions are involved: U.S.A., France and Germany
  - Global competences, global expertise, global best-practice
  - Huge experience feed-back from customers spread over the world
  - Method development benefits of AREVA global best-practices
  - Huge validation and verification data base, unique by diversity and covering range in all relevant domains of reactor physics
- AREVA globalism guaranties
  - High quality, high accuracy, robust C&M with comprehensive V&V
  - Best support to U.S. NRC review activities and efficient solving of regulatory issues

Codes & Methods Development
The Challenge

- **Safety authority requirements are evolving**
  - Constantly increasing safety requirements (new knowledge on physical phenomena)
  - Post-Fukushima effect
  - New generation of engineers question traditional solutions / assumptions/ legacy C&M
- **Nuclear energy suppliers need**
  - effective margin management
  - comprehensive validation of C&M to allow smooth licensing without penalties
  - accurate prediction of capability and behavior of their reactors
- **Fuel suppliers have to anticipate evolutions and come up with C&M that properly meet new needs**

Codes & Methods Development AREVA Answer

- **AREVA took up the challenge to significantly advance the state-of-the-art in nuclear methods and started in 2002 a selection of large R&D programs preparing the next generation of C&M for fuel assembly design, core design, safety analysis and core monitoring.**
- **Advances in IT offers the opportunity to more realistic simulations**
- **The new generation of AREVA C&M is being implemented for industrial use**
- **AREVA advanced methods respond well to current challenges**

The Main C&M Development Projects (1/2)

▸ State-of-the-art neutronics/ TH/ TM	ARCADIA®
▸ Advanced fuel rod performance design code	GALILEO
▸ Advanced methods for FA TH optimization	CFD METHODS
▸ Advanced Thermal-Hydraulics	F-COBRA-TF
▸ Universal Core Monitoring	ARGOS
▸ BWR Transient and LOCA Analysis	AURORA-B

The Main C&M Development Projects (2/2)

▸ CHF Evaluation Tools	DELPHI
▸ Modernization of S-RELAP5 and coupling with ARCADIA®	S-RELAP5 ARCHITECT
▸ PWR LOCA/ non-LOCA Methods Recovery	S-RELAP5 METHODS
▸ FA Mechanical Behavior	MIKOS

ARCADIA® and COPERNIC3
Two Examples of Worldwide Projects

Richland

Lynchburg Paris Erlangen

Lyon

Developers and users are spread over the world, working on international teams
The global competence and experience in AREVA are used

AREVA Converged Basic Codes
(As Planned for DOE MOX Project)

PWR

- ARGOS
- S-RELAP5/ ARCADIA®-1
- ARCADIA®-1 APOLLO2-A/ ARTEMIS/ COBRA-FLX/ FRM

BWR

- POWERPLEX
- AURORA-B (S-RELAP5/ MB-2K)
- CASMO4/ MICROBURN-B2/ THRP
- RAMONA-5

GALILEO

S-RELAP5 (RENEWAL PROJECT: ARCHITECT)

Using synergies between regions

AREVA Converged Basic Codes
Next Evolution Step

PWR | **BWR**

ARGOS

S-RELAP5/ ARCADIA®-2

ARCADIA®-2
APOLLO2-A/ ARTEMIS/ F-COBRA-TF/ FRM

RAMONA-5

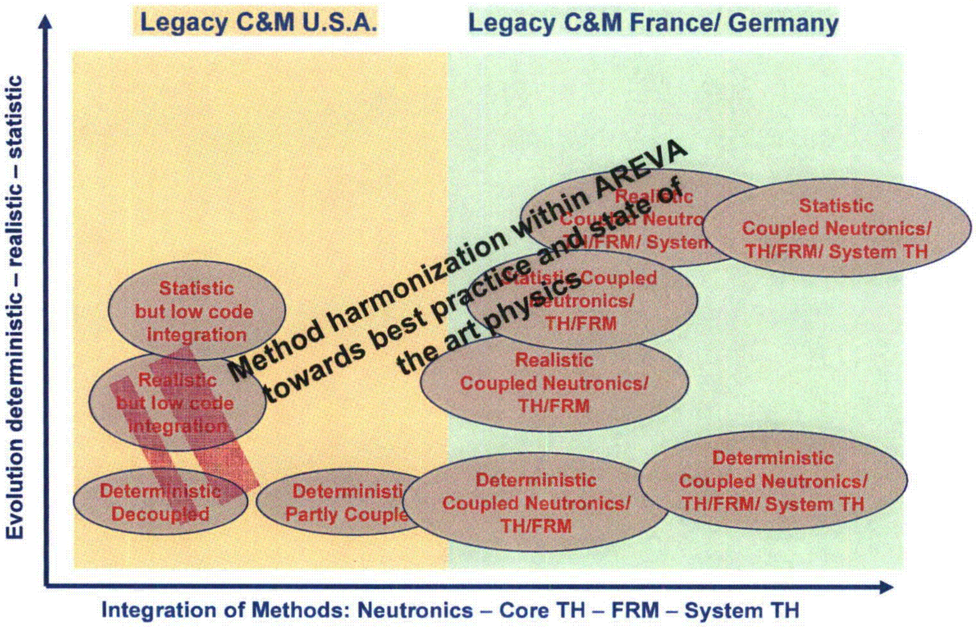
GALILEO

S-RELAP5 (RENEWAL PROJECT: ARCHITECT)

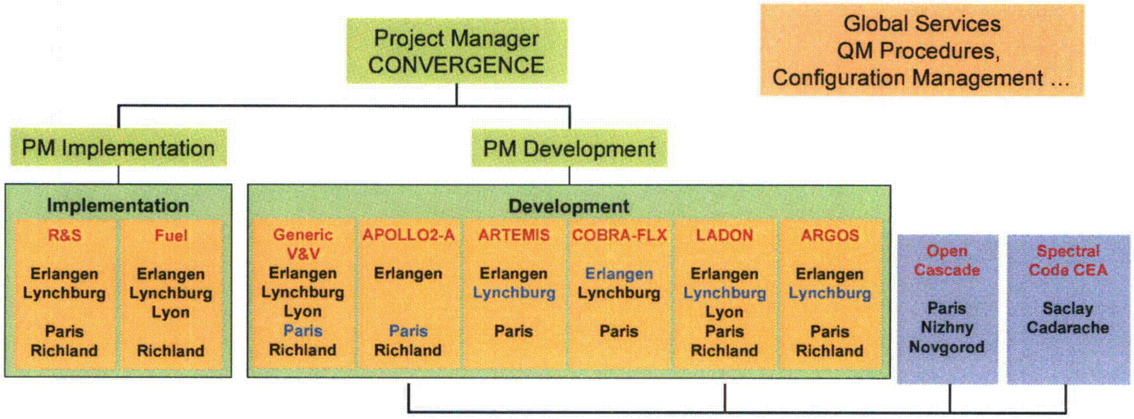
CATHARE-2 (Alternative)

Using synergies between P & BWR

AREVA Harmonization of Methods



CONVERGENCE Project
Example of Global R&D Organization



Global Support to Local Issues

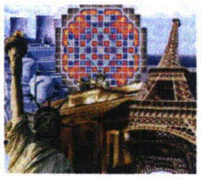
- Regional regulatory issues are resolved with global support when needed: AREVA global expertise and experience can be activated any time
- Specific customer issues can be efficiently and creatively resolved by using global competences

Exemplary Global Codes & Methods Development Projects

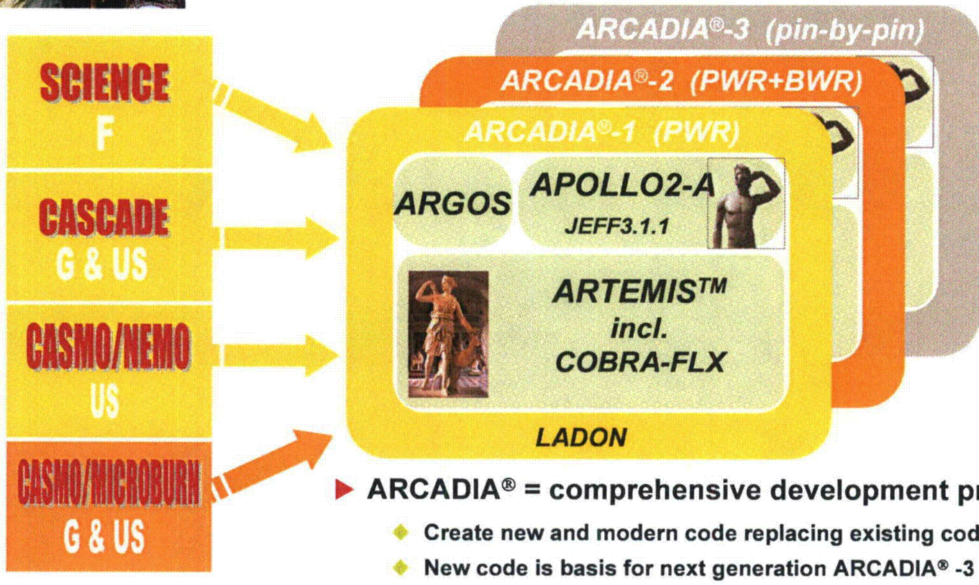
- ❑ ARCADIA®
- ❑ GALILEO
- ❑ AURORA-B

ARCADIA® Objectives

- **ARCADIA® = AREVA's future industrial, coupled neutronics / core thermal-hydraulics / thermal-mechanics code system for PWR and BWR fuel assembly and core design calculations as well as safety analysis**
  - **In-house CONVERGENCE of codes (world wide and PWR + BWR)**
    - Global competences and experiences → one of the world's leading code systems
    - Global verification and validation base → efficient licensing for comprehensive application range
  - **Modern code system for the long term future**
    - State-of-the-art physics (increase accuracy, robustness, pave the way to advanced methodologies...)
    - Optimized algorithms, software engineering, automation and modern graphical user interfaces → efficient code system
    - Code design allows long term evolution → towards more realistic core modeling



Overview of ARCADIA® The Three Main Versions



- ARCADIA® = comprehensive development program
  - Create new and modern code replacing existing codes
  - New code is basis for next generation ARCADIA® -3

ARGOS Universal Core Monitoring System

	POWERPLEX	POWERTRAX	FIDMS	PIMS	MAGELAN	ARGOS
MIP	✓	✓			✓	✓
AMS		✓				✓
SPNDs	✓	✓	✓	✓		✓
TC					✓	✓
ENFC					✓	✓

» ARGOS to cover all plants and to replace existing core monitoring systems

ARCADIA® Represents AREVA's Best Practice+

ARCADIA® Enlarged Validation Base

- Enlarged validation base (more critical experiments, more isotopic measurements, more cycles of different reactor types, fuel types, reload strategies) enables
  - Increased acceptance by S.A. & easier licensing
  - Reduction/ suppression of provisions/ penalties thanks to
    - More accurate models
    - Systematic benchmarking against reference codes or measurements
  - Extended application range to support new projects and products (predictive capability)

Qualification Domain of ARCADIA®

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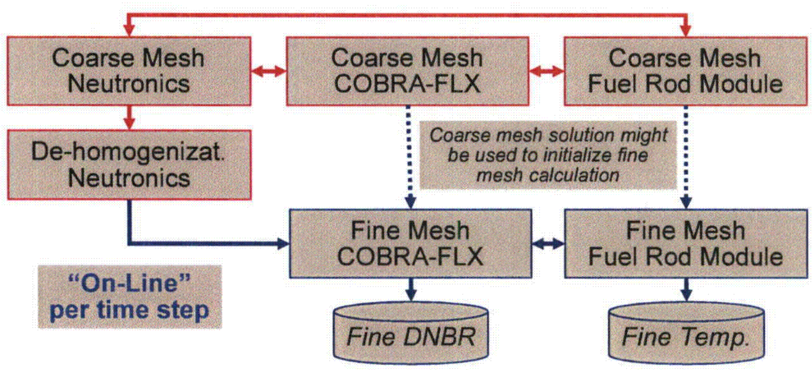
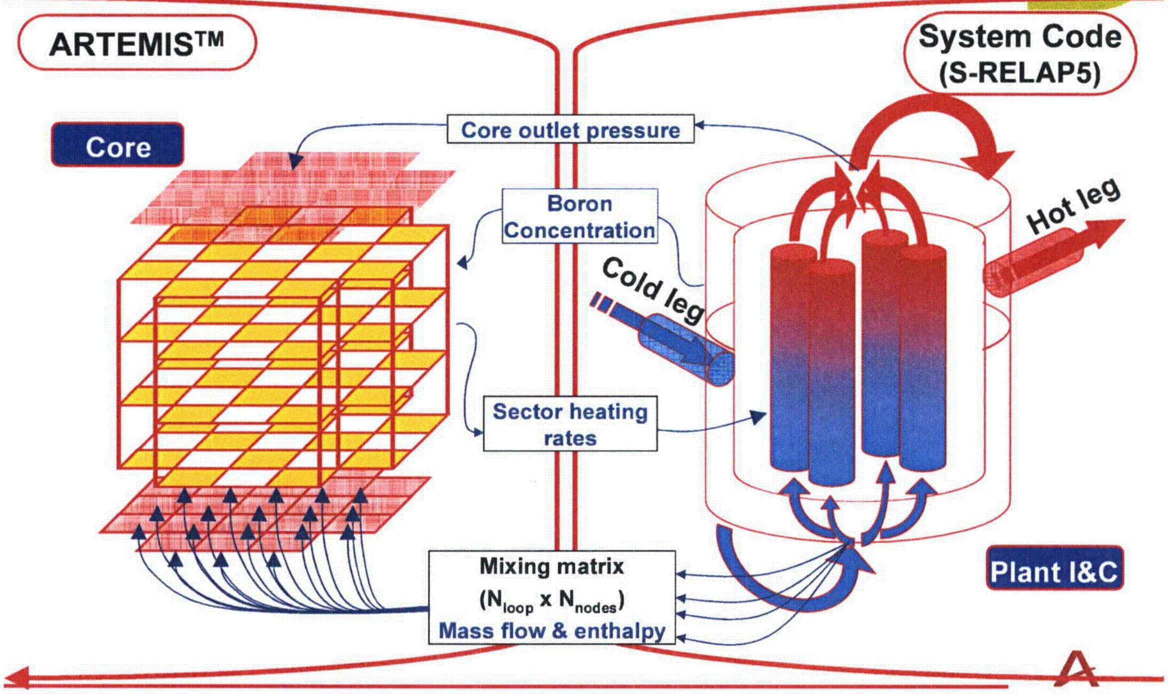
Evolution of Methods
Full Core Fine-Mesh Evaluation for Steady State and Transients

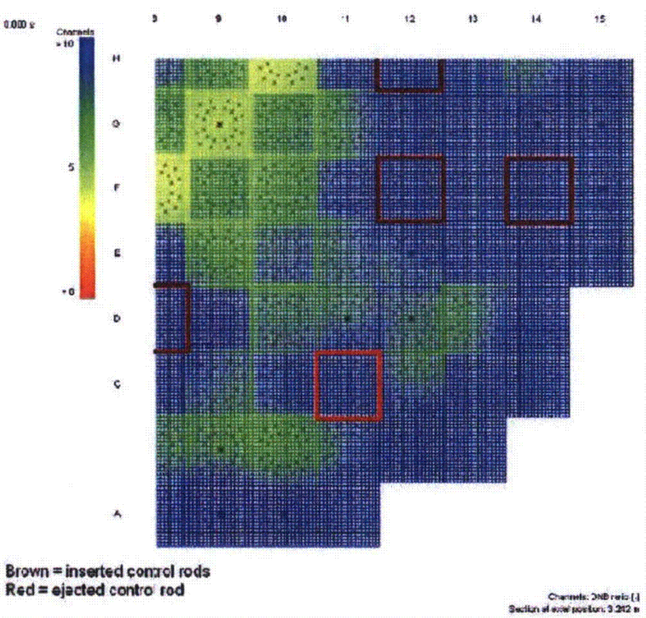


- **Fine Mesh: TH = sub-channel-by-sub-channel; FRM = pin-by-pin**
- **Available for industrial applications for steady state and transients**
  - **full core transient calculations with fine mesh evaluation in ~ 1 hour on 12 CPUs**
- **Full consistency between steady state and transient calculations (same code, same data and same models)**

Evolution of Methods
ARTEMIS™ Coupling with System Code



Evolution of Methods
Benefits for Transient Analysis

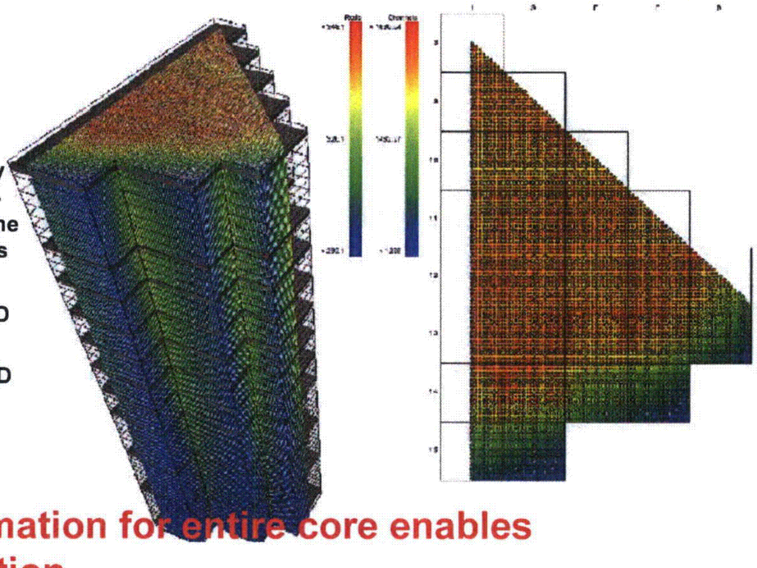


- **Example: Rod Ejection**
- **Improvements**
  - **Straight forward description of core = rods and sub-channels**
    - No virtual objects like lumped or penalized channels / rods
  - **No need to define region of interest prior to calculation**
  - **Full core 3D information allows**
    - more precise analysis
    - more insight / understanding
- **Benefits**
  - **Avoid assumptions & approximations = gain robustness & physical foundation**
  - **More insight = more efficient problem solving**
  - **Access to local information**

ARCADIA® - New Applications by Access to Local Information

Rod Surface Temperature and Sub-Channel Enthalpy

- CRUD deposition is a local phenomenon, depending on local TH and temperature conditions
- ARCADIA®, with its capability of full core pin-wise and sub-channel wise evaluation, is the ideal basis for CRUD analysis
  - Today: ARCADIA® provides input for CRUD model (chemistry)
  - Next step: Include CRUD module in ARCADIA®



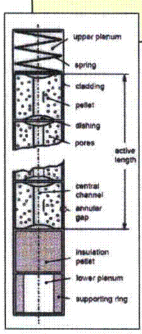
» Full 3D information for entire core enables CRUD prediction

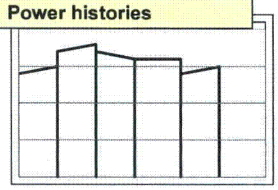
COPERNIC3 Project Overview

- A single code for all applications worldwide
- Methodologies adapted to various customers/ safety authorities

INPUT DATA

Rod characteristics	Irradiation conditions
Pellet & cladding geometry	Thermal-hydraulic conditions
Material	Power histories





Pellet and cladding thermics + clad corrosion

GALILEO

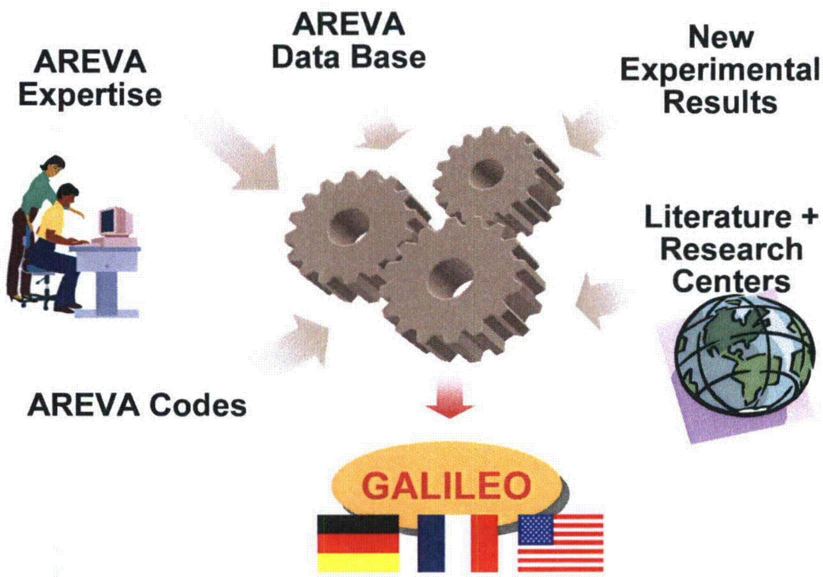
Pellet and cladding mechanics

Fission gas release Helium balance

OUTPUT RESULTS

Fuel and clad temperatures
Fuel and clad stresses and strains
Outer zirconia thickness and hydrogen content
Fission Gas Release and Helium balance
Rod internal pressure

COPERNIC3
Project Resources



GALILEO Large Calibration Database Covering Entire Burnup Range of Interest

GALILEO Fuel Rod Performance Code Major Advanced Modeling Features

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Methodology Development / Implementation

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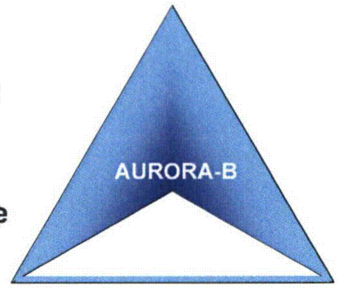
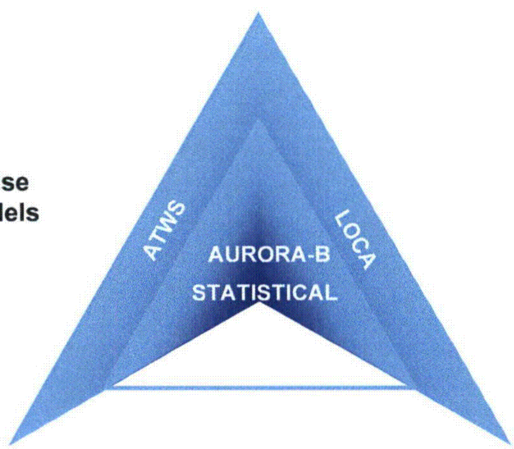
AURORA-B
Next Generation Safety Analysis

- **AURORA-B evaluation model is a best-estimate multi-physics code assembled from proven components**
  - **RODEX4**
    GALILEO BE fuel performance predictions
  - **MB2-K 3D kinetics based on MICROBURN-B2**
  - **S-RELAP5 modern two-fluid T/H system code**
- **S-RELAP5 is the host code in which relevant kernels of RODEX4 or GALILEO and MB2-K have been incorporated**
- **Same executable for PWR non-LOCA, SBLOCA, RLBLOCA (rev 2)**

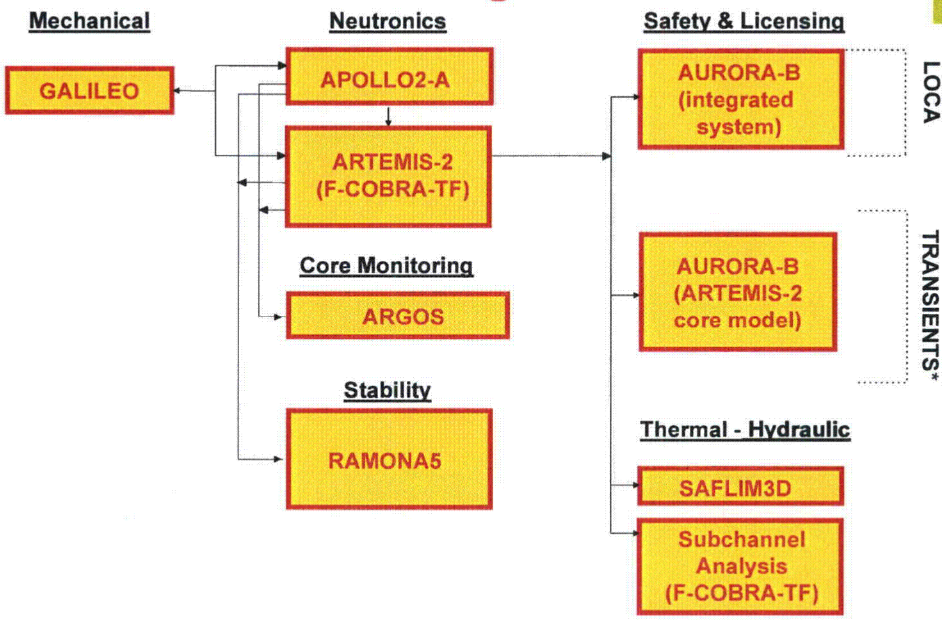


AURORA-B - an Opportunity to Advance Methodologies

- **AURORA-B Deterministic AOO**
  - **Submitted Dec. 2009**
- **AURORA-B LOCA Methodology**
- **AURORA-B ATWS Methodology**
  - **Utilize San Jose containment expertise to implement BWR containment models**
  - **Goal: Submit 2nd quarter 2014**
- **AUORA-B CRDA Methodology**
- **AURORA-B Statistical AOO**



AREVA US BWR Methodologies Long Term Future State



Conclusions

- AREVA started implementing a new generation of advanced Codes & Methods integrating state of the art physics
- The new methods can accommodate changing regulatory requirements and customer needs worldwide
- AREVA C&M development is unique by its global dimensions
  - All regions are involved: U.S.A., France and Germany
  - Global competences, global expertise, global best-practice
  - Huge experience feed-back from customers spread over the world
  - Method development benefits of AREVA global best-practices
  - Huge validation and verification data base, unique by diversity and covering range in all relevant domains of reactor physics
- AREVA globalism guaranties
  - High quality, high expertise, robust C&M with outstanding V&V
  - Best support to U.S. NRC review activities and efficient solving of regulatory issues

Topical Report Submittals

Pedro Salas
Director, Regulatory Affairs

AREVA

Generic Topical Report Review Status

- ***Generic Topical Reports***
  - ***Increase efficiency of licensing process***
  - ***Improve effectiveness and use of qualified licensee and regulatory resources***
- ***AREVA is working with customers for both short and long term***
  - ***Improve safety of plants***
  - ***Evolution of technology***
  - ***Resolution of concerns***

Generic topical reports create significant savings in manhours to NRC

Generic Topical Report Review Status

[ ]

Generic Topical Report Review Status

[ ]

Generic Topical Report Review Status

- *Review Status*
  - *Over 4 years: 1*
  - *Over 3 years: 1*
  - *Over 2 years: 6*
  - *Over 1 year: 1*
  - *Less than 1 year: 6*
- *Reports critical to safety improvements*
- *Reports critical to implementation of new codes and methods*
- *Supplemental reports are result of NRC and AREVA dialogue to address gap*
- *Long term solution is to have advanced methods topicals for replacement of legacy topicals*

We are committed to action!

Topical Reports to be Submitted

Topical Reports to be Submitted

Topical Reports to be Submitted

- ***AREVA is committed to***
  - ***Resolving technical issues quickly***
  - ***Long term improvements***
  - ***Frequent interfaces and dialogue with the NRC***
- ***Our customers are engaged***
  - ***Length of reviews may disincentive customers to improve technology***
  - ***Length of reviews may encourage the continued use of legacy methods***

» Use of Generic Topical Reports improves efficiency of licensing process for licensees and regulator

Method Issues 2012 Update

Rod Kliewer
Contract Manager, Front End

AREVA

Objective

- Acknowledge issues
- Demonstrate commitment
- Articulate AREVA's vision
- Seek alignment with NRC's vision and constraints

AREVA takes the issue seriously and remains committed to action

Background

Recent History

[ ]

Recent History

Impacts

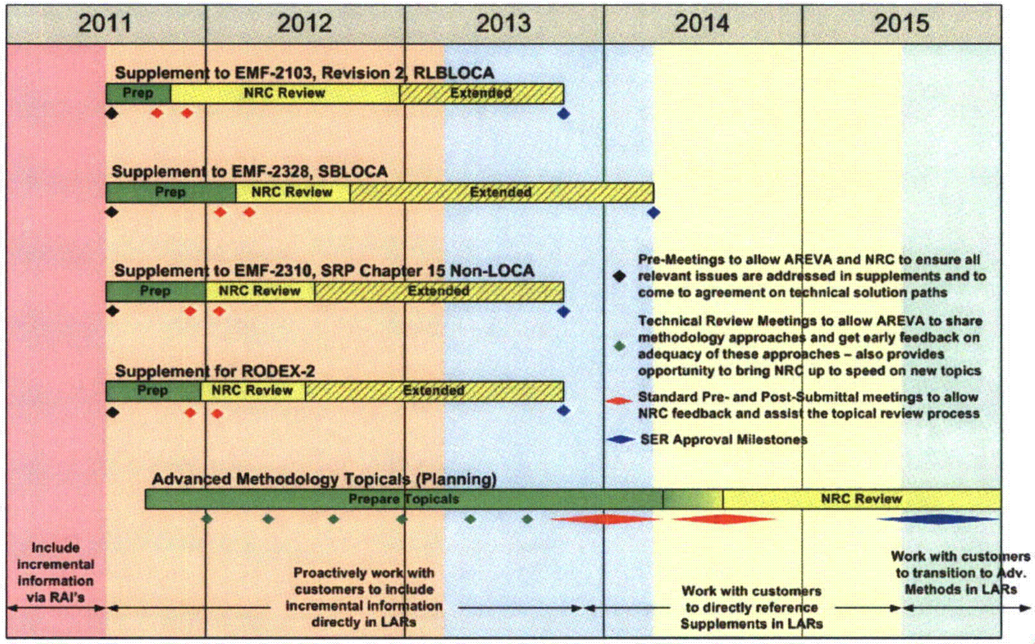
Status of Methods Recovery

PWR Methods Supplements

	Fuel Performance	Realistic LBLOCA	Small Break LOCA	Non-LOCA Safety Analysis
Pre-submittal meetings	Q2,Q3 of 2011	Q3 of 2011	Q3 of 2011	Q3 of 2011
Supplement Submitted	December 2011	December 2011	March 2012	December 2011
Planned Target SER Issuance	June 30, 2012	December 15, 2012	September 10, 2012	July 31, 2012
NRC Target SER Issuance	December 2012	December 2013	March 2014	December 2013

AREVA Still Stands by Its Commitment

Licensing Roadmap



AREVA's Strategy

The AREVA Fuel Excellence Plan Our roadmap to deliver expectations

Strategic Alignment to Safety

Strategic Objectives

Moving Forward

Immediate Future

Long-Term Solution

Wrap Up

[

]

Questions?

Alignment?

Thermal Conductivity Degradation Letter Update

Douglas Pruitt
Manager/FDT-AR

AREVA

Thermal Conductivity Degradation (TCD)

- In 2009, the NRC asked AREVA to evaluate the impact of thermal conductivity degradation on licensing analyses
- A BWR white-paper was prepared and provided to NRC
- In March 2012, the NRC completed their internal review of the white-paper and issued some requests for additional information
  - Specific requests to complete NRC evaluation
  - Comments for further clarification
- The NRC also stated that the TCD issue is considered an error and AREVA should provide reporting information (50.46 or SAFDLs that are in jeopardy) to our customers.

COMMENTS FOR CLARIFICATION

Thermal Conductivity Degradation

AREVA

TCD Letter Update
Comments 6.13.2.1 & 2

- **Anticipated Transients Without Scram with Instability**
- **Extended Power Uprate**
  - **Generally speaking, mitigating actions remain appropriate and applicable because the highest rod line for EPU operation remains identical to the highest rod line for the maximum extended load line limit analysis (MELLLA) operation.**
  - **AREVA agrees, no issue identified**
- **MELLLA+**
  - **Staff remains concerned regarding ATWS instability for MELLLA+ expanded operating domain in which the core power-to-flow ratio at the onset of an ATWS event may be higher.**
  - **AREVA does not have a generically approved method for the analysis of ATWS events.**
  - **AREVA agrees...**

TCD Letter Update
Comments 6.13.2.1 & 2

- **Anticipated Transients Without Scram with Instability**
- **Two AREVA customers are planning on submitting LARs that involve MELLLA+ operation with AREVA ATRIUM 10XM fuel**
  - **Licensing approach is based on TRACG plant specific analyses based on AREVA supplied information on the ATRIUM 10XM fuel performance**

[ ]

TCD Letter Update
Comments 7.1.1.2

- **Thermal-Mechanical Criteria, Fuel Melting**
  - **The staff finds the impact of TCD in the legacy codes results in biases in the prediction of margin to the CFM.**
  - **While calculations show that limits continue to be met, the legacy methods do not provide an acceptable basis for quantifying the margin without consideration of these biases.**
  - **The staff anticipates that the impact of accounting for the bias would be further exaggerated for calculations performed using RODEX2, especially since RODEX2 does not have the same FGR model as RODEX2A and, therefore, would continue to predict very low overall fuel rod thermal resistance relative to expectations based on the most recent available test data.**
  - **However, transient calculations will always bound the steady-state calculations, analyses to demonstrate margin to the limit for AOOs will ensure that the fuel design limits protect against CFM during steady-state operation.**

TCD Letter Update
AREVA Response 7.1.1.2

- **Thermal-Mechanical Criteria, Fuel Melting:**
  - **RODEX2 is not used by AREVA to calculate FCM.**
  - **The FCM analyses are performed using RODEX2A.**
  - **The White Paper RODEX2A assessment conservatively quantified the FCT margin to fuel melt that results from lack of TCD capability as being ~250 degrees F**
    - Worst case rod (8%Gd) and Worst point in the pellet exposure history (~8 MWd/kgU),

    when considering the lower bound 95/95 temperature value (under-prediction) from benchmarking data
  - **AREVA, as standard practice, performs analyses for each fuel cycle design and assures that margin to CFM is maintained.**
  - **AREVA will modify our analyses guideline to assure positive margin to CFM when applying a melt temperature adjustment to accommodate TCD. The amount of any final adjustment (if needed) will be established by AREVA.**
  - **AREVA RODEX4 T-M code does have TCD capability and is now being employed for fuel reload cycle designs for some customers, with further implementation contingent upon customer acceptance and LAR approval.**
- **Completion Schedule (guideline mod) ~August 30, 2012**

TCD Letter Update
Comments 7.1.1.3

- **Thermal-Mechanical Criteria, Cladding Strain**
  - **The quantified change in temperature resulting from the fuel thermal conductivity degradation at 20 MWd/kgU at the highest LHGR was calculated to be approximately [ ] °F.**
  - **Using the RODEX4 relationship, the predicted non-conservatism in the calculated cladding strain is [ ] percent. While [ ] percent seems small, the staff notes that this bias is substantial relative to the limit of 1 percent.**
  - **The non-conservatism in the legacy code RODEX2A has been determined to be approximately [ ] percent at the typically limiting exposure point.**
    - Given that this occurs at a relatively low exposure, the staff anticipates that the RODEX2 non-conservatism will be substantially similar.

TCD Letter Update
AREVA Response 7.1.1.3

- **Thermal-Mechanical Criteria, Cladding Strain**
  - **RODEX2 is not used by AREVA to calculate clad strain.**
  - **Clad strain analyses are performed using RODEX2A and the NRC-accepted method using the AREVA RAMPEX code.**
    - RODEX2A clad strain calculations are conservative (higher values) with respect to values calculated by RAMPEX.
  - **In the BWR White Paper, AREVA established the conservative value of 0.15% strain (at the max temperature increase point which occurred at 20 MWd/kgU burnup) as the incremental strain difference determined by RODEX4 with and without TCD being considered.**
    - This adjustment was then applied to a conservatively limiting clad strain value using the limiting rod type (8% Gd rod). It was found that the limiting clad strain was 0.8%
    - With the 0.15% adjustment a conservative estimate for TCD impact added to address the lack of TCD, the 1% delta clad strain criteria was still met.
  - **There is more margin to the 1% strain limit when using the NRC-accepted clad strain calculation from RAMPEX**
    - Typically the clad strain is <0.8% with RAMPEX.

TCD Letter Update
AREVA Response 7.1.1.3, continued

- **Thermal-Mechanical Criteria, Cladding Strain**
  - **AREVA will modify our analyses guideline to assure that for each future reload analyses, available positive margin is maintained to the 1% strain limit after adjustment is made to accommodate the TCD impact.**
  - **Note that the AREVA RODEX4 T-M code does have TCD capability and is now being employed for fuel reload cycle designs for some customers, with further implementation contingent upon customer acceptance and LAR approval.**
- **Completion Schedule (guideline mod) ~August 30, 2012**

TCD Letter Update
Comments 7.1.3

- **Conclusions Regarding Steady-State Calculations**
  - **The staff has reviewed the nature of the AREVA safety analysis methodology and the use of the RODEX codes to calculate steady-state figures of merit for comparison against applicable steady-state criteria.**
  - **Three thermal-mechanical criteria were evaluated: rod internal pressure, fuel centerline temperature, and cladding strain.**
  - **The staff found that the rod internal pressure calculations performed specifically using the RODEX2A code are acceptable despite biases in the prediction of the fuel conductivity with exposure.**
    - **However, this conclusion may not be applicable to equivalent analyses performed using RODEX2.**
  - **In terms of the fuel centerline temperature analysis, the staff finds that the impact of biases in the fuel thermal conductivity model in the legacy codes results in biases in the prediction of margin to the CFM.**
  - **For cladding strain, the non-conservatism in the legacy code RODEX2A has been determined to be approximately [ ] percent at the typically limiting exposure point.**

TCD Letter Update
AREVA Response 7.1.3

- **Conclusions Regarding Steady-State Calculations**
  - **RODEX2 is not used by AREVA to calculate BWR CFM, clad strain, or rod pressure. These calculations are performed by RODEX2A (CFM and rod pressure) and RAMPEX (clad strain).**
  - **The previous AREVA responses above on CFM (NRC Letter Section 7.1.1.2, above) and clad strain (NRC Letter Section 7.1.1.3, above) address the NRC summary comments.**
  - **No additional actions**

TCD Letter Update
Comments 7.2.3.1

- **Thermal-Mechanical Criteria, Transient Thermal Overpower**
  - **Figures 3.4 and 3.7, while demonstrating that the CFM limits are still met once the biases in fuel temperature are taken into account using the RODEX2A code, show significant reduction in the analysis margin.**
  - **This minimum margin tends to occur relatively early in exposure (at approximately 10 MWD/kgU), where the bias in the temperature calculations are small.**
  - **However, these biases do represent a significant change in the available margin on a relative basis. The margins to CFM tend to increase with exposure as the LHGR fuel design limit decreases with exposure above 19 MWD/kgU.**

TCD Letter Update
AREVA Response 7.2.3.1

- **Thermal-Mechanical Criteria, Transient Thermal Overpower**
  - **The minimum margin to CFM indeed does occur at low burnup (~10 MWd/kgU, per BWR White Paper, Figure 3.7).**
  - **The margin shown at this point is conservatively ~ 200 – 250 degrees F (considering the worst case rod — 8% Gd rod, accounting for TCD impact, and at the PAPT transient condition).**
  - **FCT calculations done in support of the White Paper with RODEX4 and RODEX2A indicated that RODEX2A predicts higher FCT than RODEX4 at burnups less than 15 MWd/kgU.**
  - **Therefore there is inherent additional conservatism within RODEX2A calculations for FCT, and higher margins actually exist beyond those shown in Figure 3.7.**

TCD Letter Update AREVA Response 7.2.3.1, continued

- **Thermal-Mechanical Criteria, Transient Thermal Overpower**
  - **The assessment by the NRC (above) indicates agreement that, although the bias in temperature calculations due to TCD are small at low BU levels, the margins to CFM increase as BU increases and higher CFM margins are achieved.**
  - **AREVA understanding is that adequate margin exists throughout the burnup range.**
  - **However, as discussed in the previous response to Comment 7.1.1.2, AREVA will modify the analyses guidelines to assure positive margin when TCD is considered. The amount of any final adjustment (if needed) will be established by AREVA.**
  - **The longer term solution to obtaining higher CFM margins is implementation of RODEX4, and is underway for some AREVA customers.**
- **No new action items beyond commitment for Comment 7.1.1.2**

TCD Letter Update Comments 7.2.3.2

- **Thermal-Mechanical Criteria, Transient Mechanical Overpower**
  - **AOO strain calculations were performed for normal and gadolinia bearing rods and demonstrate that the predicted strain using the legacy methods may be as high as [ ]**
  - **These calculations were performed using the RODEX2A code with a standard PAPT factor of [ ] percent.**
  - **When the calculated bias is applied at the limiting exposure (20 MWD/kgU), the margin to the acceptance criterion is very small, approximately [ ] percent.**
  - **Given the significance of the analysis bias ([ ] percent) relative to typical strain margins ([ ] percent) at the limiting exposure point, the staff concludes that continued reliance on the RODEX legacy T-M analysis methods does not provide reliable quantification of margin to the acceptance criteria.**

TCD Letter Update
AREVA Response 7.2.3.2

- **Thermal-Mechanical Criteria, Transient Mechanical Overpower**
  - **See previous response to NRC comments in Section 7.1.1.3 above re: the adequacy of the calculated AREVA fuel clad strain margin.**
  - **The quantification on impact of TCD on clad strain was established using RODEX4 and applied to a conservative limiting clad strain value for reload analyses.**
  - **The AREVA quantification of the impact is appropriate based on the additional information provided in the Section 7.1.1.3 response above.**
- **No additional actions other than the commitments in 7.1.1.3**

TCD Letter Update
7.4.1.2

- **Large Break LOCA**
  - **Another sensitivity calculation was performed for a plant with a limiting PCT that occurred at a higher exposure.**
  - **This calculation was performed at the limiting exposure point, and the PCT was increased by 18 °F when the adjusted input parameters were used in HUXY.**
  - **The staff notes that PCT sensitivities of this magnitude are not considered significant.**
  - ***The staff's criterion for significance is 50 °F, as provided in 10 CFR 50.46. However, the staff notes that licensees must track errors of any magnitude for annual reporting, in accordance with the 10 CFR 50.46 requirements for LOCA evaluation models***
  - **AREVA has transmitted 10 CFR 50.46 reports to all Licensees**
  - **Further discussion required on future EXEM-BWR-2000 Licensing submittals and reporting**

TCD Letter Update Comments 7.4.1.3

- **Small Break LOCA**
  - For SBLOCA evaluations, the core remains cooled during the blowdown phase because the inventory loss during this phase is small.
  - Therefore, the PCT is expected to occur late in the LOCA transient once core uncovery occurs (i.e., under SBLOCA conditions, early dryout of the fuel bundles is not expected to occur).
  - The long-term behavior of SBLOCA calculations tends to match large-break loss-of-coolant accident (LBLOCA) calculations following actuation of the automatic depressurization system. Therefore, conclusions drawn from the previously mentioned calculations would apply to SBLOCA evaluations.
  - AREVA believes SBLOCA impact addressed by LBLOCA responses, no further action for SBLOCA.

TCD Letter Update Comments 7.4.1.4

- **LOCA Conclusions**
  - The staff concludes that predictions of PCT following core uncovery using the EXEM-2000 methodology are unlikely to be significantly impacted by the effect of fuel thermal conductivity degradation with exposure.
  - This is because the primary variable that the conductivity affects is the initial stored energy in the core, which is largely removed during the blowdown stage of the LOCA.
  - AREVA agrees, no further action.

TCD Letter Update
Comments 7.4.1.4

- **LOCA Conclusions**
  - However, in particular cases in which the limiting bundles in the core are, in terms of predicted PCT, exposed bundles (as opposed to fresh bundles), the PCT impact may still be substantial. The results calculated by AREVA have indicated a case where the PCT would increase by 18 °F.
  - However, RELAX does not appear to calculate the onset of boiling transition during the early stages of a LOCA.
  - During the blowdown stage, the critical power response of the bundles is likely to be a stronger function of the initial stored energy. Therefore, the sensitivity calculations performed by AREVA do not fully address the potential that exposed bundles may be the LOCA limited bundles, if the LOCA analyses considered the effect of stored energy on early boiling transition.

TCD Letter Update
Comments 7.4.1.4

- **LOCA Conclusions**
  - Therefore, the staff cannot conclude that the AREVA BWR white paper fully demonstrates that the LOCA PCT analysis sensitivity to the fuel thermal conductivity degradation is below the significance threshold of 50 °F.
  - As provided in the April response, AREVA notes the 18 °F impact reported in the whitepaper was for an exposed bundle that exhibited early boiling transition lockout and included the differences in stored energy due to thermal conductivity degradation.
  - Because future calculations may be impacted by TCD, AREVA is modifying the method to perform TCD sensitivity studies consistent with the whitepaper.
  - 50.46 reporting letters for all US customers have been sent which indicate a 0 °F impact for this methodology modification
  - Future LARs will include this modification to the method as a plant specific approved method
  - A 50.46 report will be made noting the appropriate adder if no LAR is related to a new LOCA break spectrum analyses for a plant.

Thermal Conductivity Update LOCA Methods

Graydon Uyeda
Engineering & Projects, Nuclear Analysis
Manager, LOCA, ECCS & BWR Analysis

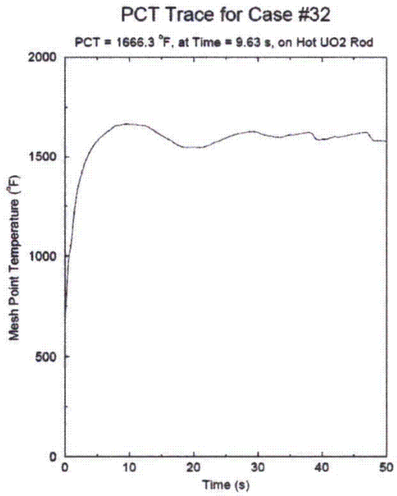
AREVA

TCD - LOCA Update RODEX Based Methods

- **Please provide**
  - **Comparison of temperature vs. time for limiting break at PCT location**
  - **Show fuel rod radial temperature profiles (uncorrected, corrected cases)**
  - **Show fuel centerline, fuel average, and clad surface temperatures versus time at PCT location (uncorrected, corrected cases)**
  - **Provide fuel average temperatures at PCT location at**
    - End of blowdown
    - Start of refill
    - Start of reflood
  - **What are the results of the study at end of cycle burnup stored energies and pin pressures?**
  - **What is the impact of EOL burn-up on fuel centerline and fuel average temperatures?**
  - **Provide information requested above at EOL conditions**

TCD - LOCA Update RODEX Based Methods

- **Comparison of temperature vs. time for limiting break at PCT location**



Reference: ANP-2903Q2(P)

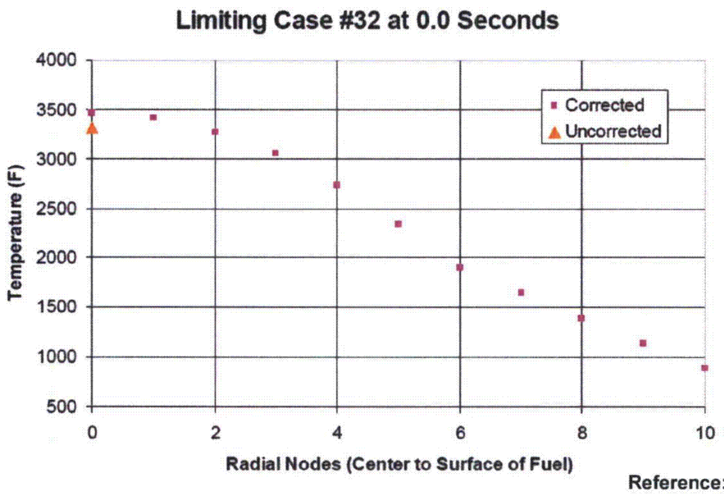
TCD - LOCA Update RODEX Based Methods

- **Show fuel rod radial temperature profiles (uncorrected, corrected cases)**
  - **To adjust for thermal conductivity degradation, the fuel centerline temperature is corrected prior to initiation of the LOCA transient. The transient is only analyzed with the corrected pellet temperature.**
  - **Because the uncorrected radial profile is never used, it cannot be provided. However, the uncorrected centerline temperature at the start of the transient can be back-calculated. This is shown in the figure on the next slide.**
  - **As the pellet power is not adjusted the radial temperature profile would follow the corrected profile closely, converging at the surface of the pellet.**

Reference: ANP-2903P

TCD - LOCA Update
RODEX Based Methods

- Show fuel rod radial temperature profiles (uncorrected, corrected cases)



Reference: ANP-2903P

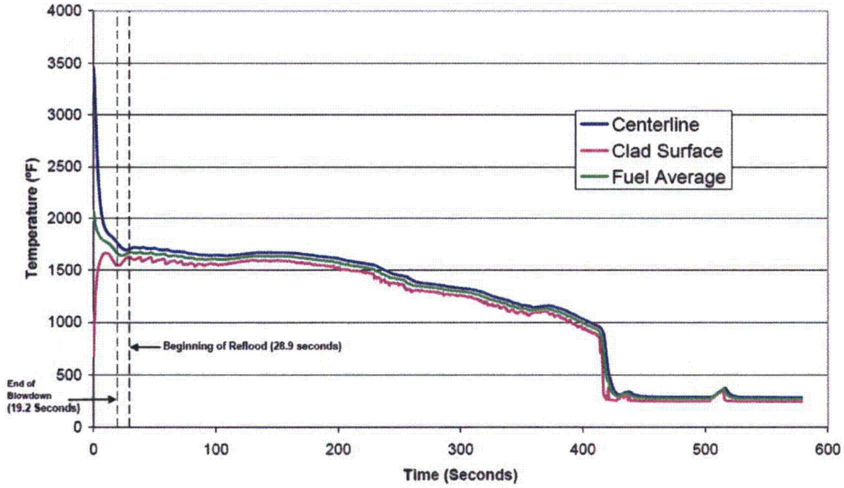
TCD - LOCA Update
RODEX Based Methods

- Show fuel centerline, fuel average, and clad surface temperatures versus time at PCT location (uncorrected, corrected cases)
- Provide fuel average temperatures at PCT location at
  - End of blowdown
  - Start of refill
  - Start of reflood

  - The figure on the following slide demonstrates the three requested temperatures versus time. Since the transient is analyzed with the centerline temperature adjusted prior to initiation of the LOCA, only the corrected temperatures are provided.
  - The vertical dashed lines indicate the requested event timing. End of blowdown corresponds to the start of refill.

Reference: ANP-2903P

TCD - LOCA Update
RODEX Based Methods



Reference: ANP-2903P

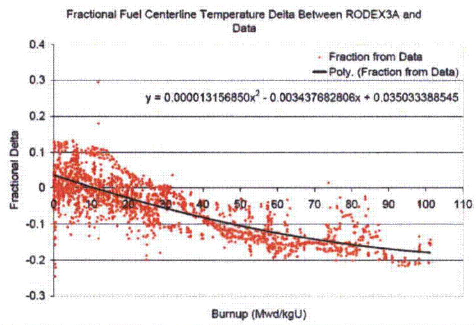
TCD - LOCA Update
RODEX Based Methods

- **What are the results of the study at end of cycle burnup stored energies and pin pressures?**
  - More information is requested about the nature of this question
  - AREVA RLBLOCA analysis evaluates the first and second cycle fuel rods. The assembly burnup is one of several sampled parameters.
  - The figures on the previous slides were derived from an analysis in which the limiting case was an end-of-cycle case. The limiting PCT occurred in a fresh UO2 rod.

Reference: ANP-2903P

TCD - LOCA Update
RODEX Based Methods

- **What is the impact of EOL burn-up on fuel centerline and fuel average temperatures?**
  - **The figure shows the RODEX3A-to-experimental data benchmarking results along with the polynomial fitted to the results. The polynomial is used to calculate the bias factor applied to RODEX3A calculated temperature.**
  - **At 62 GWd/mtU, the bias factor would be: Tnew/Toriginal=1.128**



Reference: ANP-2903P

TCD - LOCA Update
RODEX Based Methods

- **Provide information requested above at EOL conditions**
  - **AREVA RLBLOCA analysis does not modeled third cycle fuel as the pellet energy and location of the assemblies will not produce a result that would challenge the LOCA acceptance criteria.**
  - **AREVA could create the figures on the previous slides for a second cycle fuel pin from the same case.**

Reference: ANP-2903P

Fuel Thermal Conductivity Degradation for B&W-Designed Plants

John Klingenfus,
Advisory Engineer
AREVA LOCA Methods

AREVA

B&W Plant LOCA TCD Agenda

- History of TCD with TACO3/GDTACO
- BWNT LOCA Methods
- BWNT LOCA EM TCD – Step 1
- BWNT LOCA EM TCD – Step 2
- TCD R&D Evaluations
- TCD Assessments to Test Rods
- Summary and Conclusions

TACO3 Fuel Performance Code History

- The TACO3 SS fuel code was developed in the late 1980s and benchmarked to available data at that time.
- Some TACO3 benchmarks were performed up to the mid 50 GWd/mtU range and sample applications up to 60 GWd/mtU were provided.
- LOCA benchmark initializations for most cases had low burnups (< 10 GWd/mtU) but some had burnups in the mid-30 GWd/mtU range.
- TACO3 was approved for use in 1989.
- TACO3 uses a BOC fuel thermal conductivity and was approved for use up to 60 GWd/mtU.
- The TACO3 steady-state fission gas release model with a bounding power history approach is used for generating fuel temperatures for input to LOCA applications.
- TACO3 was used as a replacement for TACO2 beginning in the early 1990s within the CRAFT2 LOCA Evaluation Model (EM) (BAW-10104).
- TACO3 is used in the current RELAP5/MOD2-B&W LOCA EM for all B&W-designed plants since the early to mid 1990s.

Fuel Thermal Conductivity Degradation History for BWNT LOCA

- The first consideration of TCD with TACO3 was with a revision to the Extended Burnup Applications from BAW-10186 in 1993-4.
- This revision ultimately extended fuel pin BU for the B&W plants 62 GWd/mtU.
- SIMFUEL data was used to increase statistical 95/95 uncertainty to account for degraded thermal-conductivity and rim effects after 40 GWd/mtU based on TACO3 LOCA initialization analyses.
- Since 1994, LBLOCA methods have
  - Increased TACO3 fuel temperature uncertainties from [0.1151] above [40 GWd/mtU by 0.003 for every GWd/mtU above 40].
  - Used same TACO3 UO_2 techniques with GDTACO for Gadolinia fuel.
- The increased fuel temperature uncertainty is used for all B&W plant LOCA analyses.

BWNT LOCA EM Methods

- LOCA analyses are performed at BOL, MOL, and EOL.
- Five axial peaking elevations are analyzed at BOL, but BOL initializations are unaffected by TCD.
- Five axial peaking elevations are analyzed at MOL and at least on at EOL. These include methods changes to address TCD.
  - TACO3 inputs and methods are modified for TIL analyses
  - Increased uncertainties are applied to the SS fuel temperatures at higher burnups
- BOL and MOL analyses may be PCT limited (e.g. PCTs in the 2000 +/- 50 F target range).
- EOL analyses are pin pressure limited with TACO3
  - The maximum LHR limit is established by the pin pressure reaching the licensing above system pressure limit.
  - PCT is calculated at EOL, but there is considerable margin to the acceptance criteria. Generally 200 to 400 F less than limiting BOL or MOL PCT.

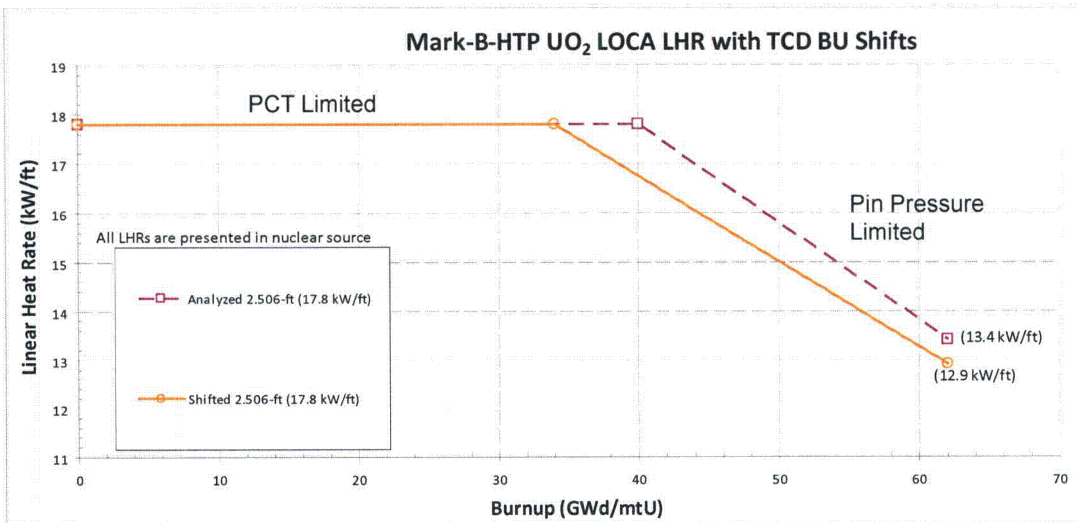
BWNT LOCA EM TCD – Step 1

- LOCA initialization techniques used for TACO3/GDTACO at TIL (MOL and EOL) introduce conservatism in the fuel temperatures used in LOCA analyses by using:
  - [A bounding fuel enrichment (high),
  - A bounding power history envelop with an increase of 7 to 10 percent on top of the envelop,
  - A 1 GWd/mtU hold at LOCA initialization power peaking,
  - The centerline fuel temp uncertainty factor conservatively applied to the volume-average temperature,
  - An increased fuel temperature uncertainty is used for burnups > 40 GWd/mtU]
- Reviewed TACO3 based techniques in 2009 in relation to the corrective action program (2009-4152). The evaluations concluded TACO3 initialization techniques were reasonable for establishing fuel temperature inputs to limiting PCT cases.
- Cursory LOCA initialization fuel temperature comparisons between TACO3, COPERNIC2, and COPERNIC3 (GALILEO) in 2009 showed acceptable values when biases were considered in the benchmark predictions.

BWNT LOCA EM TCD - Step 2

- **TIL burnups comparisons between TACO3 fuel temperatures at MOL or EOL based on GALILEO code predictions since 2009 have resulted in changes to methods of analysis or adjustments to reload licensing fuel LBLOCA LHR limits based on local versus rod-average burnup.**
  - LOCA LHR limits for MOL burnups were reduced by ~15% (e.g. 6 GWD/mtU at MOL or to 34 from 40 GWd/mtU) to account for local versus rod-average BU differences. This has been implemented during new LBLOCA analyses since 2010 or during the reload process for all B&W plants except for CR-3, who is currently not operating, but they will evaluate this during the next reload (both pre-EPU prior to restart and EPU).
  - B&W plant LOCA analyses reduced the EOL LHR limit by 0.5 kW/ft to account for high burnup TCD. At EOL, the LHR reduction accounts for local to rod-average burnup to determine the fuel temperature and PCT increase. This has been implemented during new LBLOCA analyses since 2010 or during the reload process for all B&W plants except for CR-3, but it will be evaluated during the next reload.

Sample LOCA LHR LIMITS with TCD Burnup Shifts



TCD R&D Evaluations

- AREVA R&D studies in 2010 were performed to identify how GALILEO could be integrated into BWNT LOCA EM analyses.
- This R&D work reaffirmed that future LOCA analyses with TACO3 inputs should use local versus rod-average burnups for the adjustments (Step 2).
- The burnup shift minimizes potential LOCA impacts (e.g. changes to LHRs or PCTs) when TACO3/GDTACO is replaced by a code with TCD explicitly modeled.
- GALILEO is leading candidate for future replacement.

TCD in BWNT LOCA Analyses

- The NRC issued IN 2011-21 in December 2011, alerting the industry of questions on TCD.
- In February 2012, the NRC issued 11 50.54(f) to 11 plants licensed with W LOCA methods that did not directly address TCD in the inputs or analyses. The letters were sent to plant will the smallest PCT margins.
- The NRC also sent a letter to W seeking additional information on initial fuel temperature methods (e.g., TCD consideration) used in non-LOCA or SBLOCA analyses.
- AREVA has received a similar letter from the NRC on non-LOCA or SBLOCA analyses.
- The B&W plants were not included except through inference.
- TCD is a topic that was already considered and addressed for the B&W plant LOCA analyses. It will be considered and addressed for Bellefonte restart as well.
- LOCA methods will continue to evolve and they will monitor TCD-related changes within the industry and regulatory framework.

TCD Assessments

- Perform benchmarks with TACO3 and GALILEO to test data from rods with TCD effects included (IFA 432 – Rod 3).
- TACO3 was conservative for all burnups and LHRs for the upper thermocouple for Rod 3 as shown in Figures 8, 10, and 11 (attached).
- GALILEO was nearly best-estimate as shown in Figure 7-35 (attached).
- TACO3 was conservative because of the xenon gas release as supported by the considerations in Figure 20 (attached).

TACO3 TCD Benchmark

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TACO3 TCD Benchmark

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TACO3 TCD Benchmark

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GALILEO TCD Benchmark

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TACO3 TCD Benchmark

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Conclusions for TACO3 Fuel Temperature Predictions for LOCA

- TACO3 is conservative with respect to TCD for high power applications due to the xenon gap degradation as evidenced in the benchmarks.
- The TIL inputs and initialization methods maximize the xenon gas release to increase the fuel temperatures.
- The 95/95 uncertainty factors applied directly account for fuel TCD effects after [40 GWd/mtU].
- Combined, the TACO3 code formulation, the methods of analysis, burnup dependent uncertainty factors, local to rod-average burnup shifts including EOL LHR reductions produce conservative fuel temperature inputs for LOCA analyses.

Questions?

U.S. PWR Fuel Product Update

AREVA

Presentation Outline

- U.S. PWR Fuel Supply
- Current PWR Fuel Designs and Planned Design Transitions
- PWR Lead Assembly Programs

Fuel Supply – U.S. Operating Plants by OEM

Fuel Designs – U.S. Operating Plants by OEM

Fuel Assembly Design Platforms - Key Fuel Assembly Components

- **The current (HTP™) Fuel Assembly Design Platforms consist of the following key attributes, which are implemented as applicable:**
  - Chamfered Pellet
  - M5™ Cladding
  - HTP™ Spacer Grid
  - Intermediate Flow Mixers (IFMs)
  - HMP™ Bottom Grid
  - MONOBLOC™ Guide Tube (only where dashpot required)
  - Welded Structure
  - Robust FUELGUARD™ Lower End Fitting
  - Quick Disconnect between Upper End Fitting and Guide Tubes (except Mark-B-HTP)

Key Fuel Assembly Components – Chamfered Pellet

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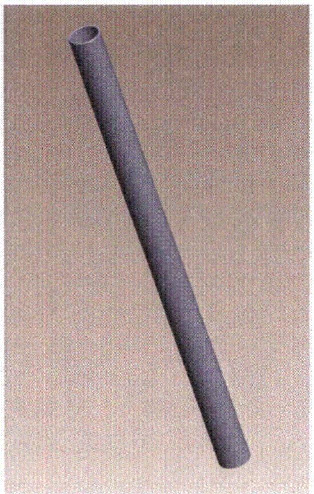
Improved margin for Pellet – Cladding Interaction (PCI) through significant decrease in flaw generation

Key Fuel Assembly Components – M5™ Cladding



Low-oxidizing alloy

Low Hydrogen pickup

Higher burnup reliability

Margin to proposed 10CFR50.46 LOCA Criteria - cladding maintains ductility post-LOCA

Ensures operating limits are not impacted due to burnup-dependent oxidation limits

Key Fuel Assembly Components – HTP™ Spacer Grid

- **Rod support and flow mixing in a single component**
  - **Balanced stiffness and damping characteristics**

Contact geometry provides optimum resistance to grid to rod fretting (GTRF) even on core periphery

Key Fuel Assembly Components – IFM Grid

- Similar line contact principle applied as with the HTP™ Spacer Grid

[ ]

Provides optimal fuel efficiency and minimal cycle costs, with added benefit of structural robustness

Key Fuel Assembly Components – HMP™ Bottom Grid

- Constructed using the same design concept as the HTP™ Spacer Grid

[ ]

No known fretting failures in fuel assemblies delivered with HTP™ Spacer Grids and HMP™ Bottom Grids

Key Fuel Assembly Components – MONOBLOC™ Guide Tube

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Provides increased fuel assembly lateral stiffness for increased resistance against fuel assembly distortion

Key Fuel Assembly Components – Welded Structure

[ ]

Direct coupling between grids and guide tubes yield increased fuel assembly stiffness, which improves resistance to fuel assembly distortion

Key Fuel Assembly Components – Robust FUELGUARD Lower End Fitting

[ ]

The Robust FUELGUARD Lower End Fitting is a proven solution in eliminating debris related fuel failures

Mark-B-HTP Design

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US PWR Fuel Designs – Mark-B-HTP Planned Design Transitions

Babcock & Wilcox Reactor Type – Issues and Solutions

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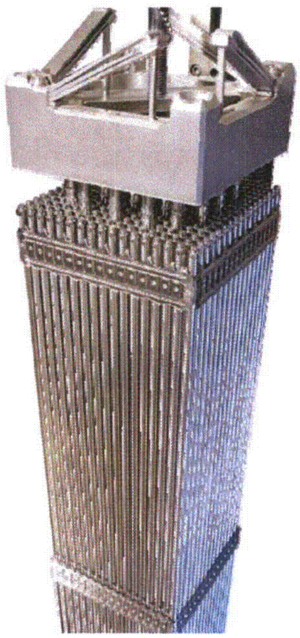
Mark-BW and W-HTP Designs



US PWR Fuel Designs – Mark-BW and W-HTP Planned Design Transitions

Westinghouse Reactor Type – Issues and Solutions

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Mark-BW Planned Design Transitions – Sequoyah Units 1 and 2

Mark-BW (Current) ***W17-HTP (Future)***

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W17-HTP Design – Reload introduction in Fall 2012

W17-HTP Planned Design Transitions – Harris

W17-HTP (Current) ***W17-HTP (Future)***

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Reload introduction initiated in May 2012

W15-HTP Planned Design Transitions – Robinson

W15-HTP (Current) ***W15-HTP (Future)***

[ ]

Reload introduction initiated in Fall 2011

CE-HTP Design

CE 14x14

CE 15x15

CE-HTP Design 16 x 16

US PWR Fuel Designs – CE-HTP Planned Design Transitions

Combustion Engineering Reactor Type – Issues and Solutions

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CE14-HTP Planned Design Transitions – FCA1, SLU1, MIL2, CCL 1&2

CE14-HTP (Current)

CE14-HTP (Future)

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Reload introduction of Advanced CE-HTP fuel initiated at CCL1 in early 2011

CE16-HTP Planned Design Transition – Palo Verde , SONGS

CE16-HTP (Current) ***CE16-HTP (Future)***

[ ]

Mini-Batch introduction at SONGS in Fall 2012

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Lead Assembly Programs

AREVA

CE Lead Assembly Programs

- 16x16

[ ]

B&W Lead Assembly Program

- 15x15

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GAIA™ Lead Assembly Program - GAIA™ Fuel Assembly Design Platform

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pacer Grid

[ ]

GAIA™ Lead Assembly Program – GAIA™ IFM Grid

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Provides optimum fuel efficiency and minimum cycle costs while increasing structural robustness

GAIA™ Lead Assembly Program – GRIP™ Bottom Nozzle

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The GRIP Bottom Nozzle provides high filter efficiency, high mechanical strength, and low pressure drop

GAIA™ Lead Assembly Program

- Ringhals

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- Olkiluoto

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GAIA™ Lead Assembly Program

- GAIA™ LFA host in U.S.

[ ]

  - Licensing considerations
    - Must address 10 CFR 50.59 questions
    - M5™ fuel rod cladding material exemption may be required

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- GAIA™ grid specific CHF correlation
  - Required for batch application only
  - LFAs are loaded in non-limiting locations

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