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Future Vision of Used Fuel Storage: “Back-End Friendly Fuel Designs and Holistic Safety Security Interface”

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Regulatory Information Conference

March 13, 2014

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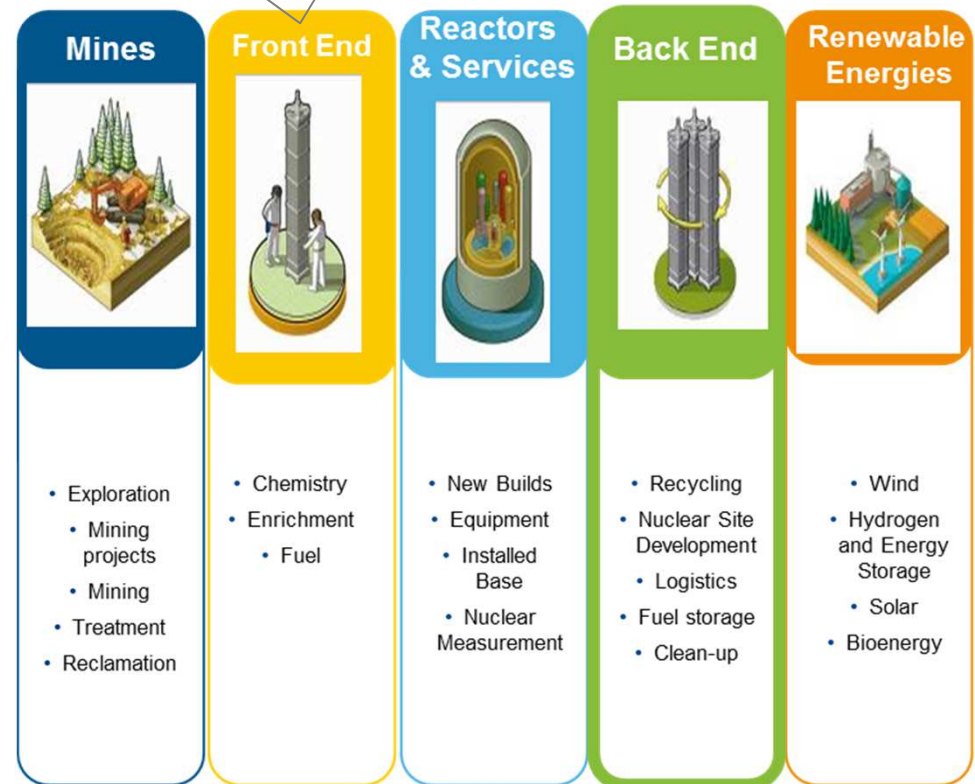
AREVA Background

▶ FUEL

- ◆ In Front End Business Group of AREVA
- ◆ Worldwide footprint: 3 fuel assembly manufacturing facilities plus JV's

▶ AREVA :

- ◆ In the Back End Business Group of AREVA
- ◆ Established in 1965 to transport nuclear materials in the U.S.
- ◆ Dry storage since 1985
- ◆ Acquired NUHOMS®* in 1998
- ◆ Market leader in dry fuel storage (nearly 900 systems loaded in USA)



*Transnuclear Inc.

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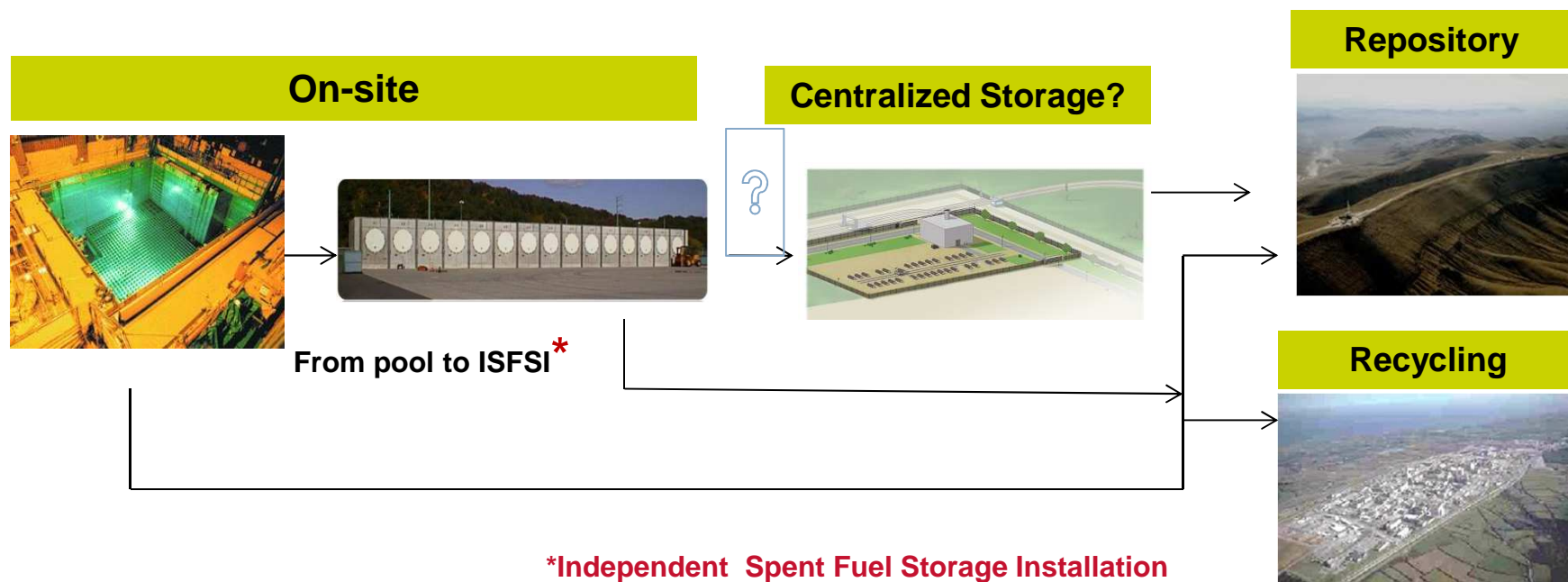
Used Fuel Management: Where are we today?

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Future Vision – Challenges Ahead



» **Complexity from Not knowing When and Where**

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Diverse Challenges Driving Diverse Needs



- ▶ **Extended Dry storage (100? 150? Years) drives Aging Management needs:**
 - ◆ High Burn-up fuel behavior
 - ◆ Storage system degradation and confinement
- ▶ **Additional Early Plant Shutdowns?**
- ▶ **Final and Sustainable Disposal Options ... Yucca Mountain?**
- ▶ **Need for Transportation Technologies and Solutions**

From the Front End Design Perspective



How can we implement a back-end friendly fuel design and holistic safety and security interface?

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Back End Friendly Design



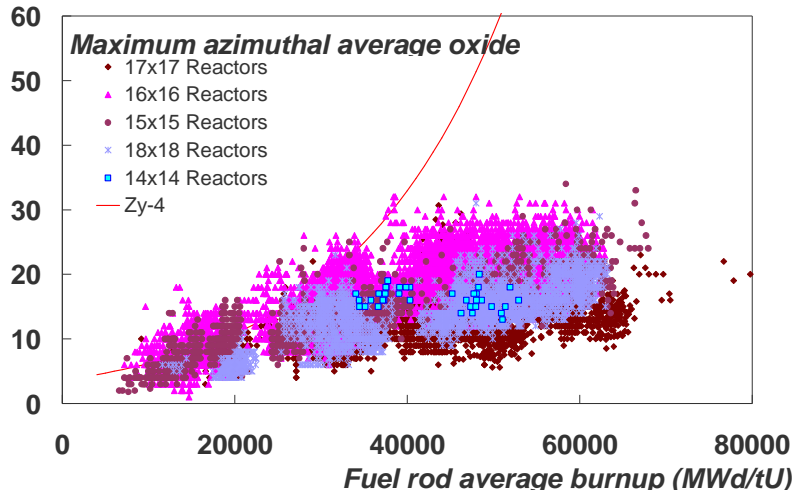
Two Main Vectors:

- ▶ **Cladding Properties Ensuring Long Term Integrity**
- ▶ **Preventing Failed Fuel Rods**

M5®: A Breakthrough Regarding Corrosion and Hydriding in the Most Extreme PWR Operating Conditions



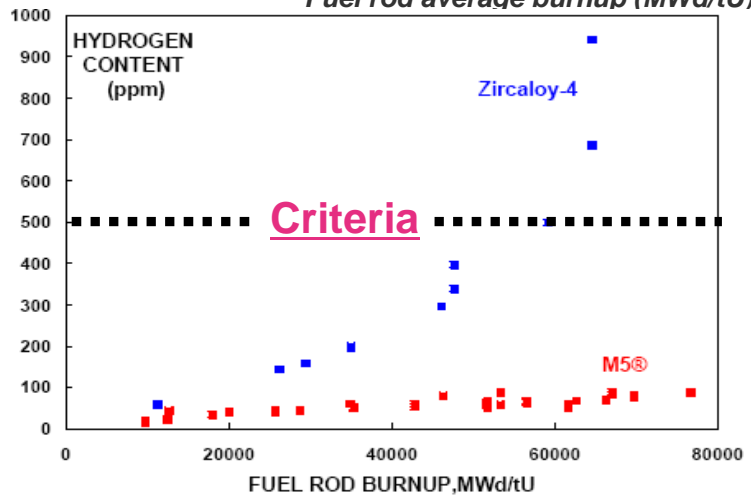
Huge Implementation on the Worldwide PWR Market for all F.A Designs ~ 5 million fuel rods in 94 PWRs up to 80GWd/tU



► Impressive corrosion resistance :

- ◆ Consistent worldwide and not exceeding 40µm
- ◆ Well Suited for the Continuing Evolution of PWR Operating Conditions

- High Lithium regime up to at least 5ppm
- Zn injection in the range 5 to 10ppb



► An extremely low hydrogen uptake:

- ◆ Lower than 100ppm:
 - Allowing plant flexibility and valuable safety margins
 - High ductility even at high fluence



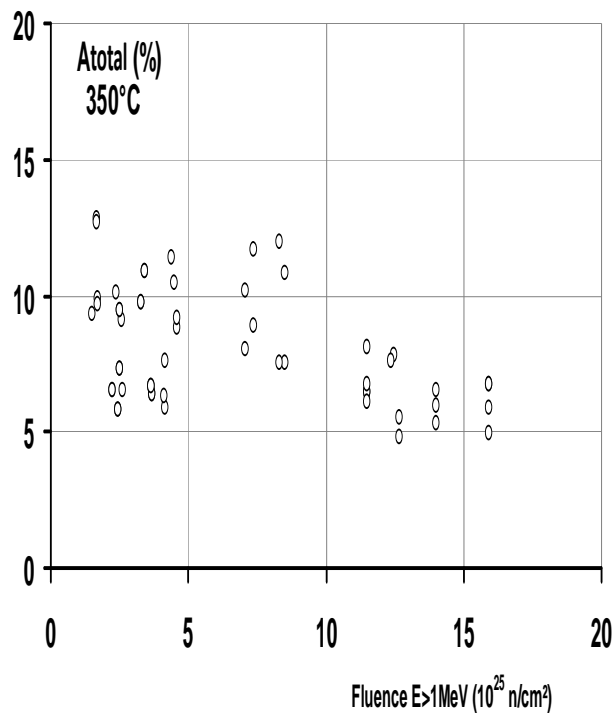
● Robust clad alloy

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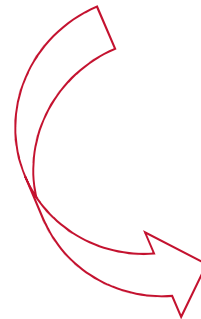


M5®: Well Suited for Long Term Storage

► High ductility even at high fluence



- ◆ Greater than 5% for M5®
- ◆ Over the 1 to 1.5~% for old Zr alloys as Zircaloy-4 with $[H]_{in-service} \sim 600 \text{ ppm}$



- No embrittlement
- High clad integrity

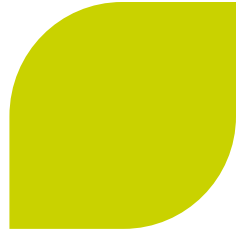
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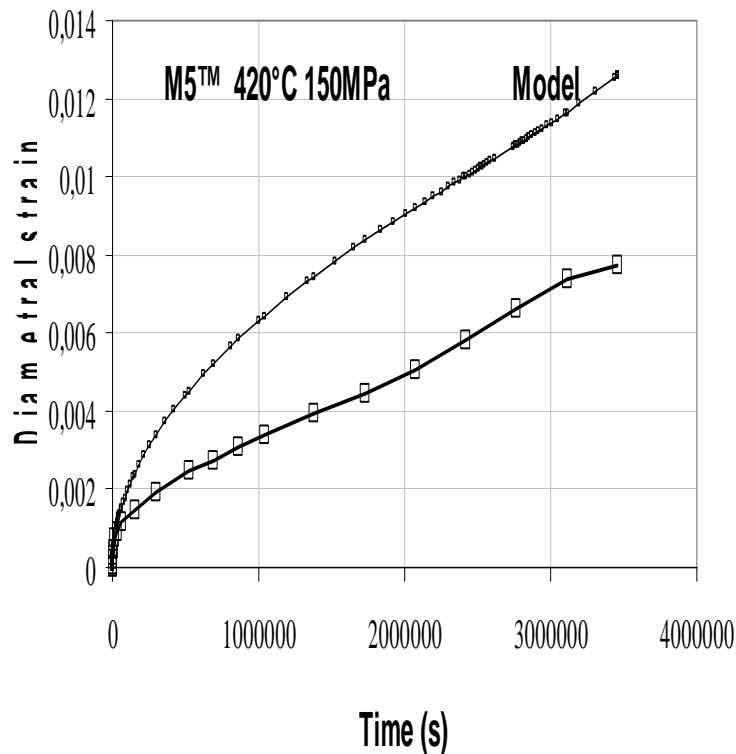

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M5®: Well Suited for Long Term Storage

(Cont'd)



► Suitable for long term storage:



- ◆ **Robust and bounding long term creep law was identified in large range:**
 - T (320 to 470° C)
 - σ (60 to 260MPa)
- ◆ **Moreover under typical decrease of the storage temperature vs. time:**
 - The natural decrease of the internal rod pressure will strongly reduced the clad creep deformation and results in additional margin
 - Extra margins on rupture deformation will be induced by annealing of the irradiation defects

Preventing Fuel Rod Failures

▶ Achieved and on-going Solutions to Fuel Issues

Designs to Resist Grid-to-Rod Fretting

- ◆ Improved Pellet Quality Standard
- ◆ CRUD Level IV Modeling
- ◆ Resistance to Fuel Assembly In-Reactor Deformation
- ◆ Resistance to Channel Bow
- ◆ Spacer Shadow Corrosion Prevention

▶ Reinforce Supplier's Performance

▶ Improve the Performance of Fuel Activities

- ◆ Human Performance Tools
- ◆ Lean 6 Sigma
- ◆ Corrective Action Program



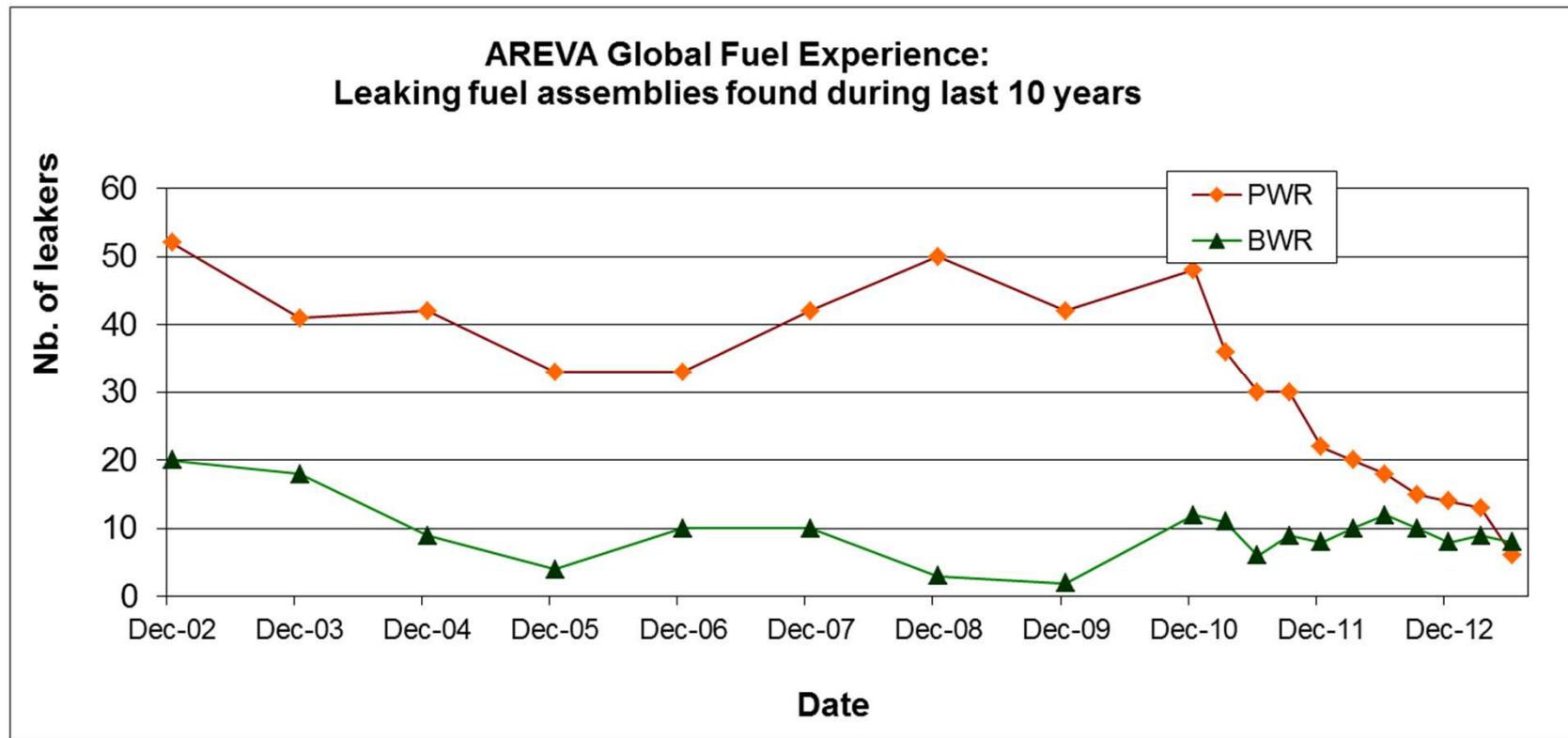
Target: Zero Failures in Reactors

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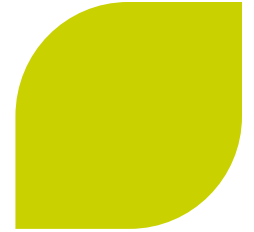
Preventing Fuel Rod Failures



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From the Back End Solutions Perspective

- ▶ Aging Management
- ▶ Integrated Triple Purpose Design
- ▶ Design Beyond a Century

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Existing Loaded Systems: Aging Management



► Monitoring of existing deployed systems

- ◆ **Concrete monitoring and maintenance is straightforward**
- ◆ **Need the tools to inspect canister for stress corrosion cracking in Chloride Induced Stress Corrosion Cracking environments**
 - AREVA pioneered tools for inspection of surface chemistry; analysis has demonstrated the effectiveness of the sampling at Calvert Cliffs
- ◆ **Future emphasis on remote-weld inspection techniques that are more sensitive than visual**
 - AREVA has initiated a project with AREVA's NDE and robotics experts to develop the concept for such a system
- ◆ **AREVA has developed a conceptual design to perform inspection for examining and cleaning canisters as they are being withdrawn into a transfer cask**

“Learning” Aging Management

- ▶ Depending on environment (marine for example), aging of dry storage systems must be periodically monitored to ensure continuous safety
- ▶ High burnup fuel behavior over longer time requires additional data:
 - ◆ In the U.S., the Nuclear Regulatory Commission stated that retrievability of used nuclear fuel (UNF) can occur for 20 years for high burn-up fuels (more than 45 GWd/tU)
 - ◆ Beyond these values, the demonstration will rely on R&D that is being defined and will be performed

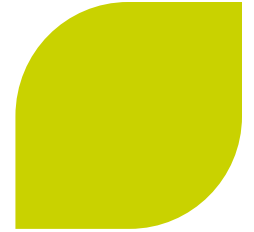
» ***AREVA is providing a TN-32 metal cask as part of the EPRI/DOE High Burnup Fuel Demonstration Project***

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Future Systems: Integrated Approach



▶ Triple Purpose System:

- ◆ Interim Storage
- ◆ Transportation
- ◆ Final repository storage

» *Reduce reconditioning/repackaging activities*

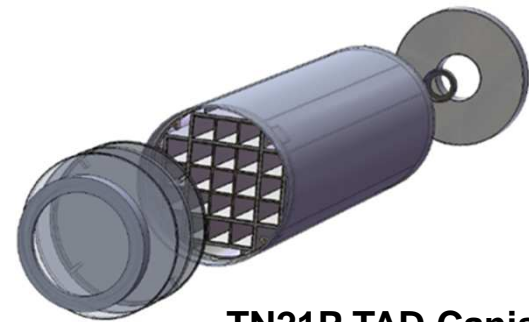
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TAD Proof of Concept Design to DOE

- ▶ TN TAD System Components
- ▶ TN21P and TN44B Canisters
- ▶ Vertical or horizontal orientation
- ▶ Disposal in horizontal orientation
- ▶ TN TAD Transportation Overpack
- ▶ Lengthened version of NUHOMS®* MP197 transport cask
- ▶ Horizontal transport of TN21P and TN44B Canisters
- ▶ Vertical aging of TN21P and TN44B Canisters



TN21P TAD Canister



TAD Aging Overpack

* Transnuclear Inc.

**Horizontal Storage Module



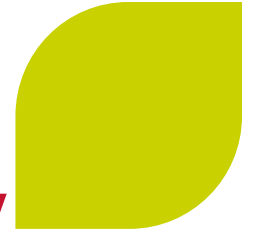
HSM** for Reactor Site Storage of TAD Canisters

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Future Systems: Design Beyond a Century



“By failing to prepare, you are preparing to fail” – B. Franklin

- ▶ **More flexibility is needed (40 years not enough)**
- ▶ **Extension of interim storage period using a more conservative analysis and design approach:**
 - ◆ **Stress corrosion cracking**
 - ◆ **Environmental, extreme weather effects**
 - ◆ **Malevolent acts**
 - ◆ **Protection of people: Dose rates**
 - ◆ **Outside/Inside Real Time Monitoring**



Summary

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Summary



- ▶ **AREVA is proactive!**
- ▶ **AREVA is deploying and developing advanced technologies for sustainable used fuel management solutions**

- ◆ **Advanced fuel cladding and robust designs for failure-free fuel**
- ◆ **Advanced, high capacity, high burn-up dry fuel storage systems**
- ◆ **Aging management inspection techniques and analyses**
- ◆ **World-leading UNF transportation experience and technologies**
- ◆ **Repository-ready transportation and disposal packages**
- ◆ **Recycling**

» **Interim Storage provides the “surge capacity” essential to any robust and sustainable used fuel management program**

» **A proactive approach to safety and security will continue to ensure effective management of risks and control of costs even as storage times are extended**

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