




AREVA

forward-looking energy



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

Michael V. McMahon – Senior Vice President, AREVA TN Americas

Ron Land – Senior Vice President, AREVA Fuel

Regulatory Information Conference

March 13, 2014

AREVA



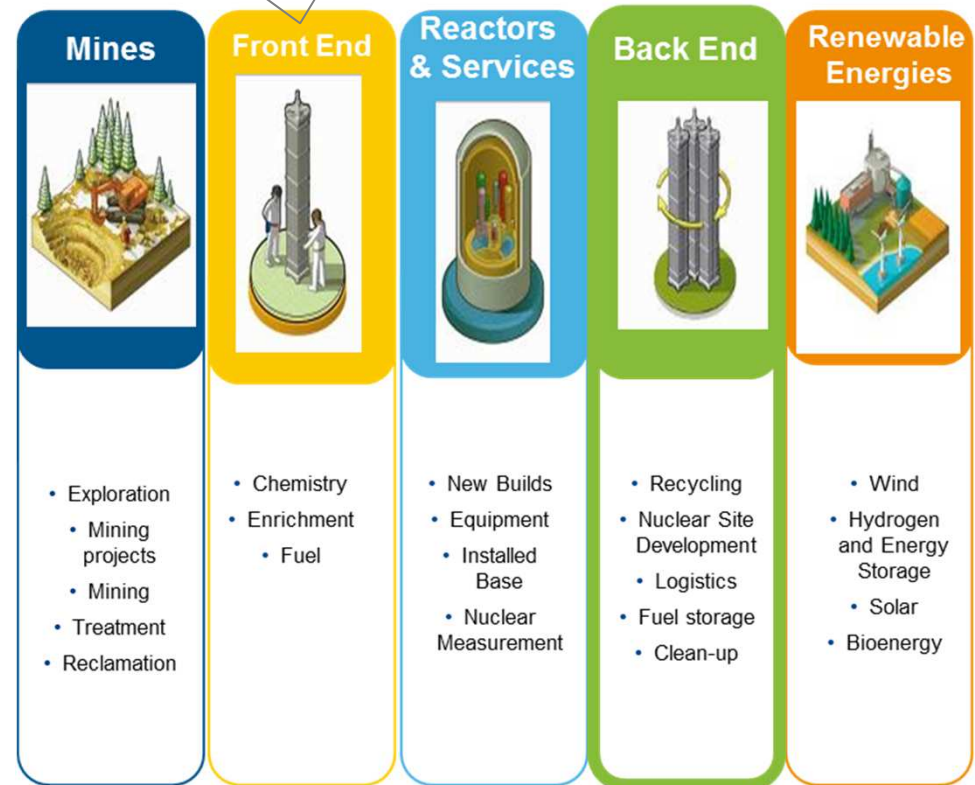
AREVA Background

▶ 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.

AREVA

Future Vision of Spent Fuel Storage – M. McMahon, R. Land – March 13, 2014 – Property of AREVA © AREVA Inc.
All rights reserved, see liability note.

AREVA
forward-looking energy



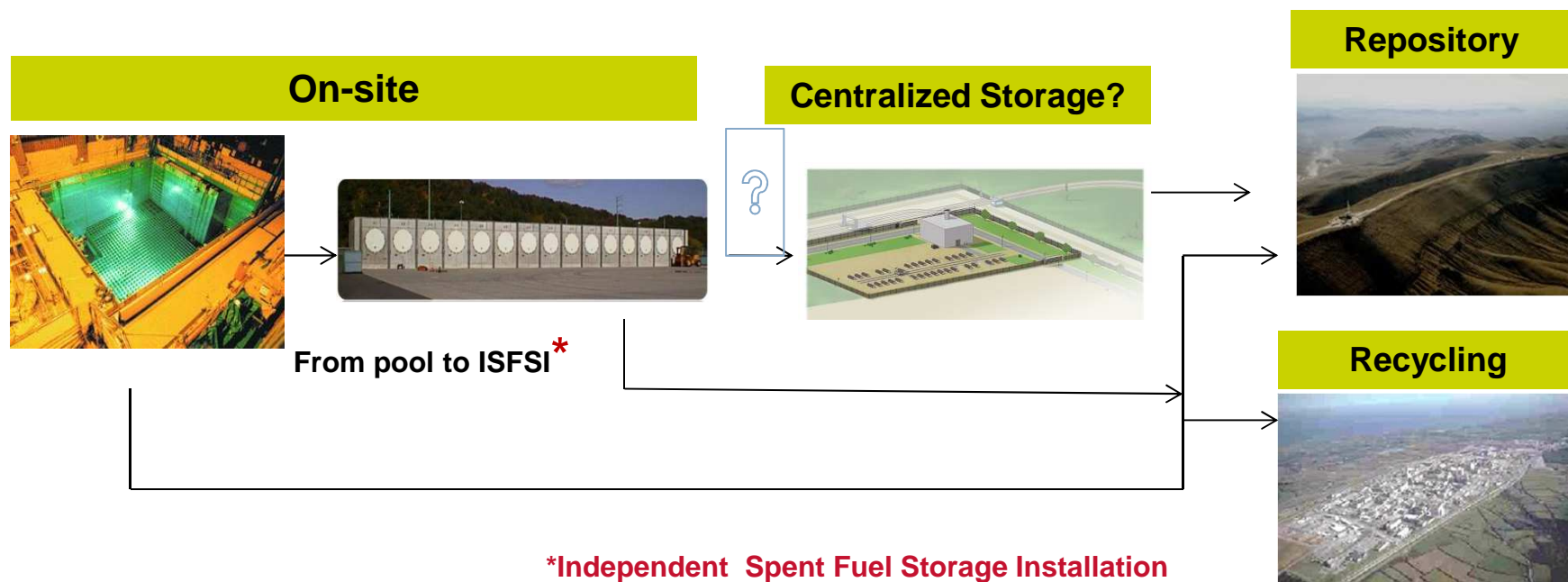
Used Fuel Management: Where are we today?

AREVA

Future Vision of Spent Fuel Storage – M. McMahon, R. Land – March 13, 2014 – Property of AREVA © AREVA Inc.
All rights reserved, see liability note.



Future Vision – Challenges Ahead



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

AREVA

Future Vision of Spent Fuel Storage – M. McMahon, R. Land – March 13, 2014 – Property of AREVA © AREVA Inc.
All rights reserved, see liability note.

AREVA
forward-looking energy

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?

AREVA

Future Vision of Spent Fuel Storage – M. McMahon, R. Land – March 13, 2014 – Property of AREVA © AREVA Inc.
All rights reserved, see liability note.

**AREVA**
forward-looking energy

Back End Friendly Design



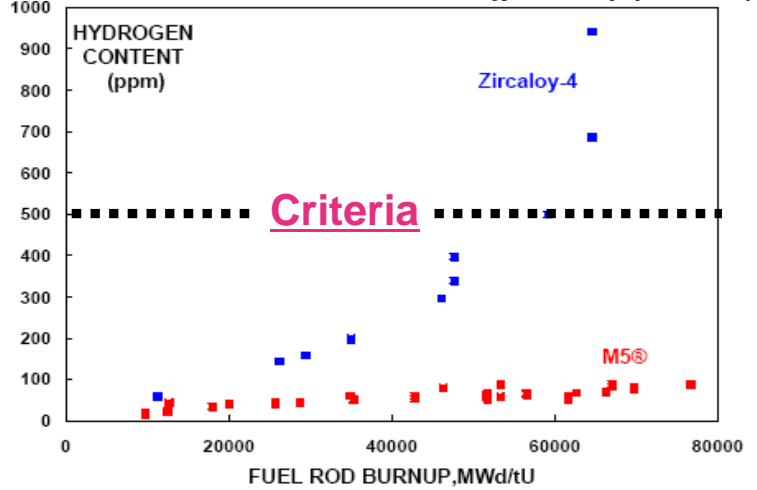
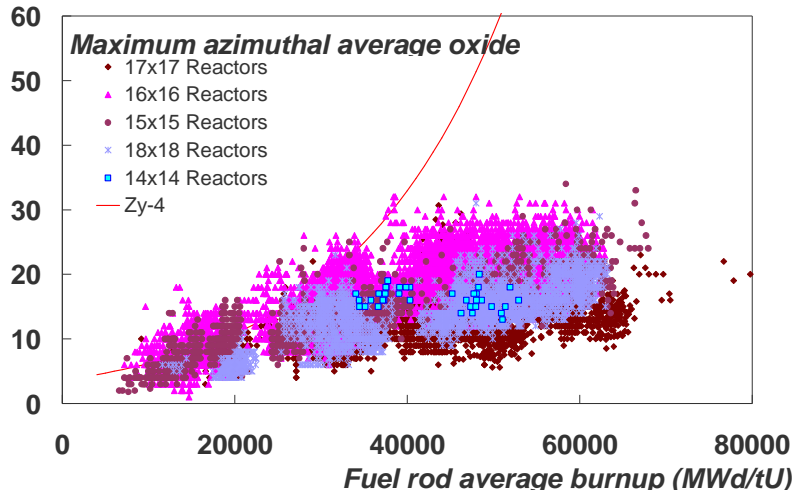
Two Main Vectors:

- ▶ **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

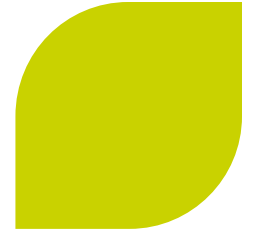


● Robust clad alloy

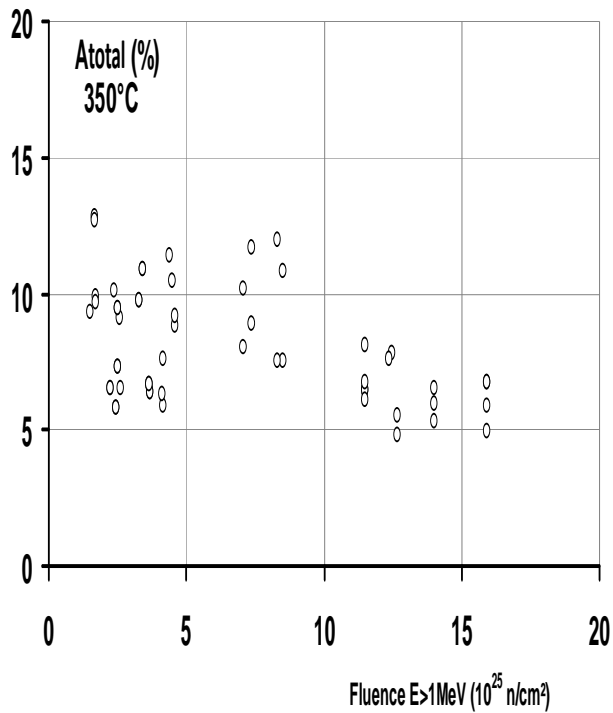
AREVA



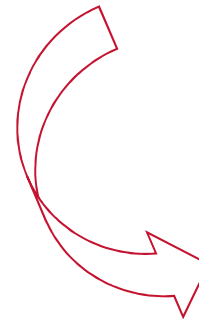
M5®: Well Suited for Long Term Storage



► 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 $[H]_{in-service} \sim 600ppm$



- No embrittlement
- High clad integrity

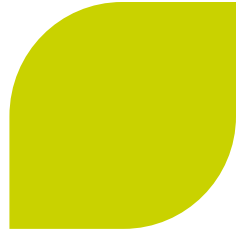
AREVA

Future Vision of Spent Fuel Storage – M. McMahon, R. Land – March 13, 2014 – Property of AREVA © AREVA Inc.
All rights reserved, see liability note.

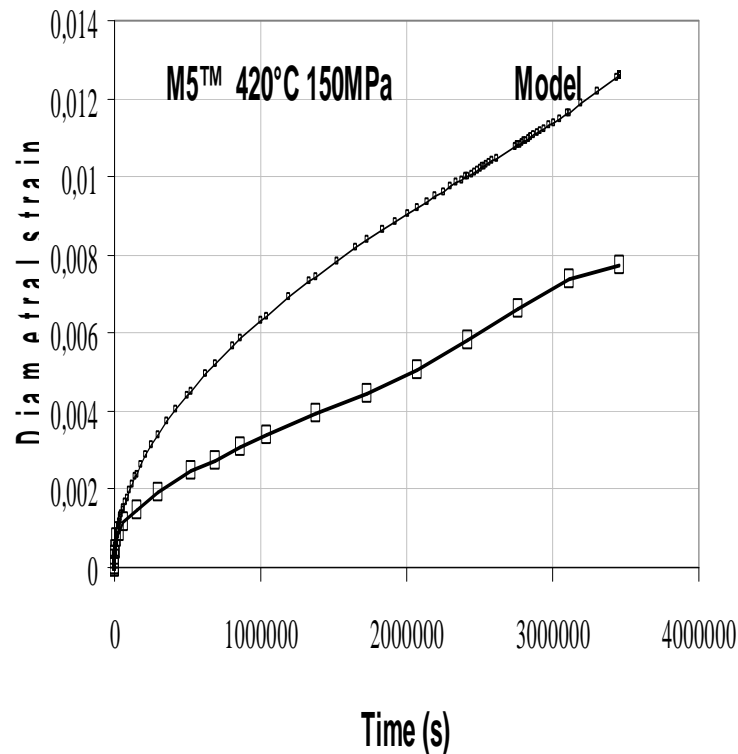

AREVA
forward-looking energy

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

AREVA

Future Vision of Spent Fuel Storage – M. McMahon, R. Land – March 13, 2014 – Property of AREVA © AREVA Inc.
All rights reserved, see liability note.


AREVA
forward-looking energy

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



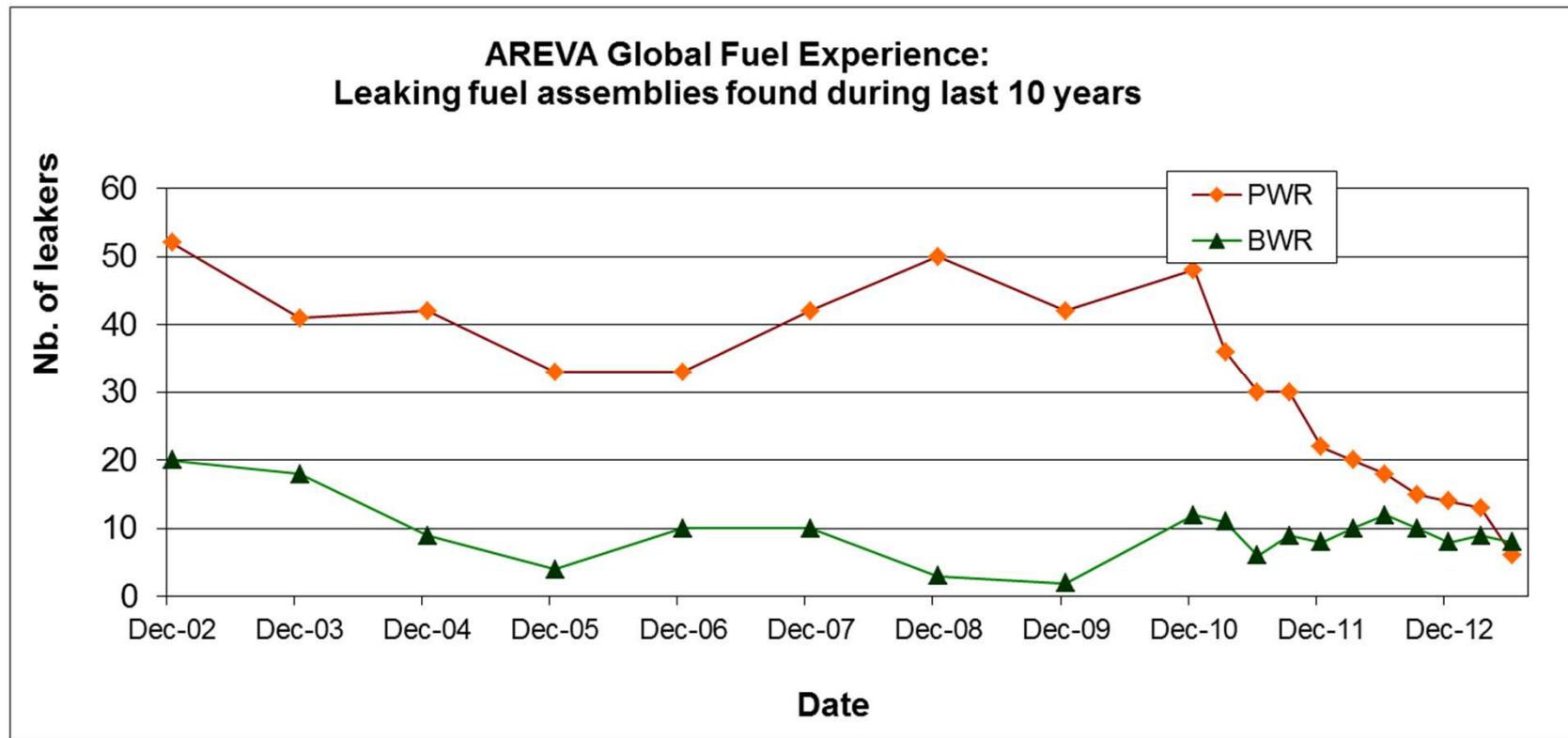
Target: Zero Failures in Reactors

AREVA

Future Vision of Spent Fuel Storage – M. McMahon, R. Land – March 13, 2014 – Property of AREVA © AREVA Inc.
All rights reserved, see liability note.

A
AREVA
forward-looking energy

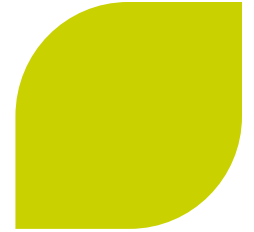
Preventing Fuel Rod Failures



AREVA

Future Vision of Spent Fuel Storage – M. McMahon, R. Land – March 13, 2014 – Property of AREVA © AREVA Inc.
All rights reserved, see liability note.





From the Back End Solutions Perspective

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

AREVA

Future Vision of Spent Fuel Storage – M. McMahon, R. Land – March 13, 2014 – Property of AREVA © AREVA Inc.
All rights reserved, see liability note.

**AREVA**
forward-looking energy

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

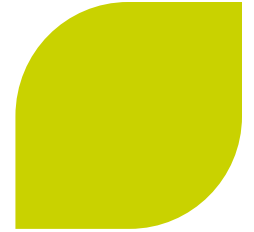
» ***AREVA is providing a TN-32 metal cask as part of the EPRI/DOE High Burnup Fuel Demonstration Project***

AREVA

Future Vision of Spent Fuel Storage – M. McMahon, R. Land – March 13, 2014 – Property of AREVA © AREVA Inc.
All rights reserved, see liability note.

**AREVA**
forward-looking energy

Future Systems: Integrated Approach



▶ Triple Purpose System:

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

» *Reduce reconditioning/repackaging activities*

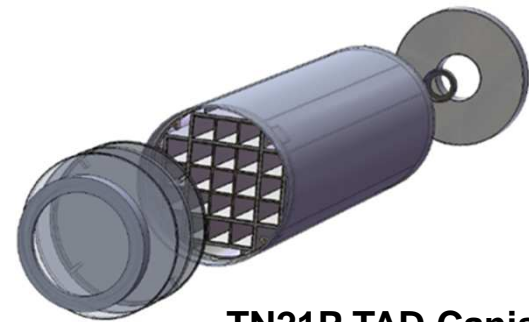
AREVA

Future Vision of Spent Fuel Storage – M. McMahon, R. Land – March 13, 2014 – Property of AREVA © AREVA Inc.
All rights reserved, see liability note.


AREVA
forward-looking energy

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

AREVA

Future Vision of Spent Fuel Storage – M. McMahon, R. Land – March 13, 2014 – Property of AREVA © AREVA Inc.
All rights reserved, see liability note.


AREVA
forward-looking energy

Future Systems: Design Beyond a Century



- ▶ **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



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

- ▶ **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**

AREVA

Future Vision of Spent Fuel Storage – M. McMahon, R. Land – March 13, 2014 – Property of AREVA © AREVA Inc.
All rights reserved, see liability note.





AREVA

forward-looking energy