IN USE: HIGH BURN-UP FUEL TRANSPORTATION

ISSUE STATEMENT

The majority of commercial spent nuclear fuel (CSNF) being discharged from light water reactors around the world is considered "high burn-up" fuel (>45 GWd/MTU). In the United States, the Nuclear Regulatory Commission (NRC) has yet to grant licenses for the transportation of CSNF exceeding this level. The lack of such licenses will inhibit the ability of U.S nuclear plant owners to ultimately remove CSNF from plant sites.

The NRC's primary concern about high burn-up CSNF is that its mechanical properties differ from those of lower burn-up CSNF, for which a large amount of data is available. Further, many nuclear plants are using "advanced" cladding materials – such as Ziron, Zirlo and M5, which were developed more recently than Zircaloy-2 and -4 – and for which the data is even more sparse. Continuing to collect detailed data on high burn-up CSNF properties is important in addressing technical concerns and requires high-cost, hot cell work.

DRIVERS

Regulatory

The NRC is not satisfied that it has an adequate technical basis to grant high burn-up CSNF transportation licenses. Some non-U.S. regulators have the same concern. This results in a demand for detailed, high burn-up CSNF property data in several technical areas, such as cladding mechanical data, radiochemical assay data, and neutron cross-section data, especially for key fission products.

Almost all of the regulatory concerns about both high burn-up and advanced claddings are ultimately related to criticality. If the cladding is brittle at high burn-up, damage during transportation, especially in the case of transportation accidents, could lead to geometric rearrangement that impact licensees' ability to perform criticality analyses

Operational

The majority of CSNF generated by U.S. and non-U.S. light water reactor operators now falls in the high burn-up range.

High burn-up used fuel is already in dry storage and will continue to expand rapidly in the future. Utilities are purchasing "dual-purpose" casks for storage and transportation, but they are proceeding at risk, given there is currently no regulation for transportation of the high-burn-up fuel presently being stored in "dual-purpose" systems.

Public Confidence

There needs to be a path in place to return a nuclear site to green field status at end of life. Without the ability to transport the fuel, it will remain on site regardless of the status of a fuel repository, centralized storage, etc.

RESULTS IMPLEMENTATION

EPRI has developed a holistic framework for resolving several CSNF transportation issues. The framework considers transportation risks, spent fuel and cask-design features, and defense-in-depth in the context of present regulations as well as in the context of future potential revisions of regulations that would reflect a risk-informed, state-of-the-art technology approach.

Within the boundary limits of the cases analyzed, the EPRI sponsored work shows that there are no credible combinations of accident events, accident locations, and fuel misloading or reconfiguration that would result in a critical configuration during the transportation of PWR spent nuclear fuel. The non-mechanistic criticality evaluation performed in the as-loaded or as-designed configuration can be considered the bounding case for all conditions of transportation, because this hypothetical reactivity case bounds all normal and hypothetical acci-dent cases that can credibly exist for spent fuel transportation packages. Further, the data collected on advanced claddings can help establish – as a part of a holistic approach – a sufficient database upon which to provide high confidence that storage and transportation of high burn-up CSNF using advanced claddings will have a near-zero likelihood of criticality. This sets the bases for granting transportation licenses for high burn-up CSNF..

PROJECT PLAN

The first part of the project plan has recently been completed: the development of a holistic approach to demonstrating that the risk of criticality during railroad transportation of CSNF, including high burn-up CSNF, is essentially zero. The foundation for the holistic approach is nearly a decade of EPRI-funded work in the areas of cladding mechanical property data collection and modeling, high burn-up radiochemical assay and neutron cross-section data collection, and detailed evaluation of the probability of a transportation accident leading to a criticality.

What remains to be done is for industry to establish the necessary technical basis for NRC (and other regulatory agencies) to adopt a more risk-informed approach. Thus, EPRI is planning to continue to interact with and resolve technical elements of concern to the NRC.

Collection of mechanical property data, primarily related to hydride reorientation effects on cladding ductility, is being pursued in collaboration with other organizations. EPRI is cofunding work related to (1) properties of hydrided cladding materials made of zirconium-based alloys containing 1% of Nb, such as Zirlo and M5, and (2) minimum cladding temperatures required to maintain cladding ductility (brittle-to-ductile transition). It is anticipated that this data collection activity will continue through 2017, and possibly longer as new advanced cladding materials are being constantly being tested and commercialized. Modeling of mechanical behavior during a transportation accident is anticipated to be completed by the end of 2018.

RISKS

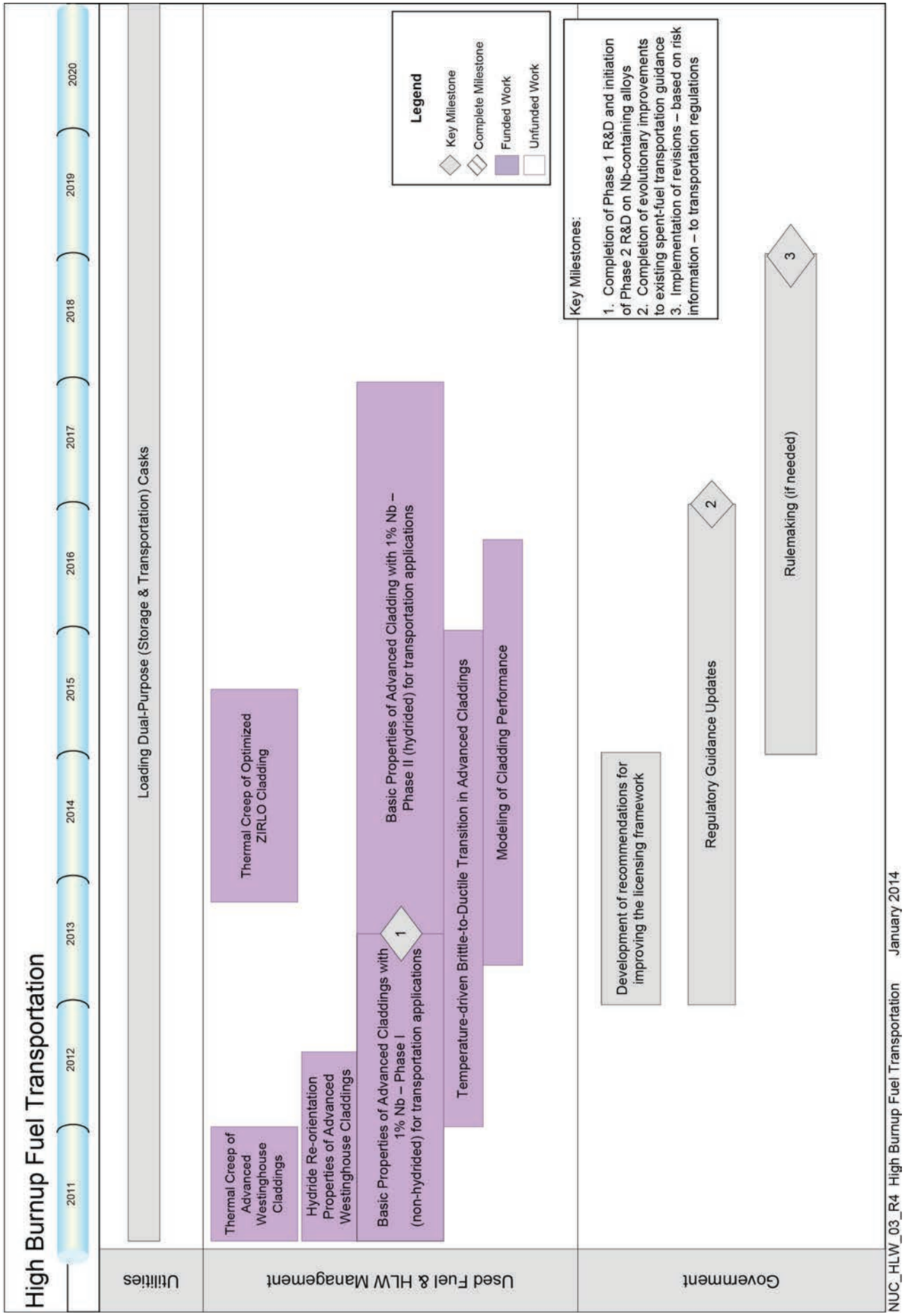
Insufficient funding to establish a sufficient database and models for advanced cladding mechanical properties. Given the majority of this work involves use of high burn-up materials in hot cells, the work will continue to require a significant part of the Used Fuel and HLW Management Program's budget.

NRC and other regulators might not embrace a risk-informed approach to high burn-up CSNF transportation regulations and regulatory decision making. This will greatly increase the amount of information required to support a large number of combinations of fuel designs, cladding alloys, operating conditions, and cask designs.

RECORD OF REVISION

This record of revision will provide a high level summary of the major changes in the document and identify the Roadmap Owner.

REVISION	DESCRIPTION OF CHANGE
0	**Original Issue:** August 2011 **Roadmap Owner:** Albert Machiels
1	**Revision Date:** January 2012 **Roadmap Owner:** Albert Machiels **Change:** Substantial revision of the first version. The initial version was modified to reflect the following changes: 1. The project seeking to seek regulatory acceptance of the EPRI-sponsored depletion benchmarks for full burn-up credit validation was moved from this Roadmap to a new Roadmap entitled "Criticality". 2. Updates of the ongoing work on cladding mechanical properties.
2	**Revision Issued:** August 2012 **Roadmap Owner:** Albert Machiels **Changes:** Clarification of previous years' technical contributions made by EPRI.
3	**Revision Issued:** December 2012 **Roadmap Owner:** Albert Machiels **Changes:** Updated to provide an additional level of details with regard to future regulatory actions.
4	**Revision Issued:** January 2014 **Roadmap Owner:** Albert Machiels **Changes:** The December 2012 version was modified to reflect the following changes: 1. Added 2014 funded work: Thermal Creep of Optimized ZIRLO Cladding 2. Updates to the ongoing work on Modeling of Cladding Performance – funded through second quarter 2016.


High Burnup Fuel Transportation
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
Utilities
Loading Dual-Purpose (Storage & Transportation) Casks
Used Fuel & HLW Management
Thermal Creep of Advanced Westinghouse Claddings
Hydride Re-orientation Properties of Advanced Westinghouse Claddings
Basic Properties of Advanced Claddings with 1% Nb – Phase I (non-hydrided) for transportation applications
1
Thermal Creep of Optimized ZIRLO Cladding
Basic Properties of Advanced Cladding with 1% Nb – Phase II (hydrided) for transportation applications
Temperature-driven Brittle-to-Ductile Transition in Advanced Claddings
Modeling of Cladding Performance
Legend
Key Milestone
Complete Milestone
Funded Work
Unfunded Work
Key Milestones:
1. Completion of Phase 1 R&D and initiation of Phase 2 R&D on Nb-containing alloys
2. Completion of evolutionary improvements to existing spent-fuel transportation guidance
3. Implementation of revisions – based on risk information – to transportation regulations
Government
Development of recommendations for improving the licensing framework
Regulatory Guidance Updates
2
Rulemaking (if needed)
3
NUC_HLW_03_R4 High Burnup Fuel Transportation January 2014