EPRI Perspectives on Modeling and Testing for Advanced Reactor Design and Licensing

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EPRI…Born in a Blackout

- Independent, nonprofit center for collaborative, public interest energy and environmental research
- International membership funds ~25% of EPRI research
  - > **40% of nuclear sector**
- EPRI programs engage ~80% of nuclear operators worldwide
- EPRI members generate > 90% of the electricity in the U.S.
  - **100% of U.S. nuclear electricity**

In 2016, EPRI launched a strategic program for Advanced Reactor RD&D to support commercialization by 2030s.

EPRI and GAIN Initiative

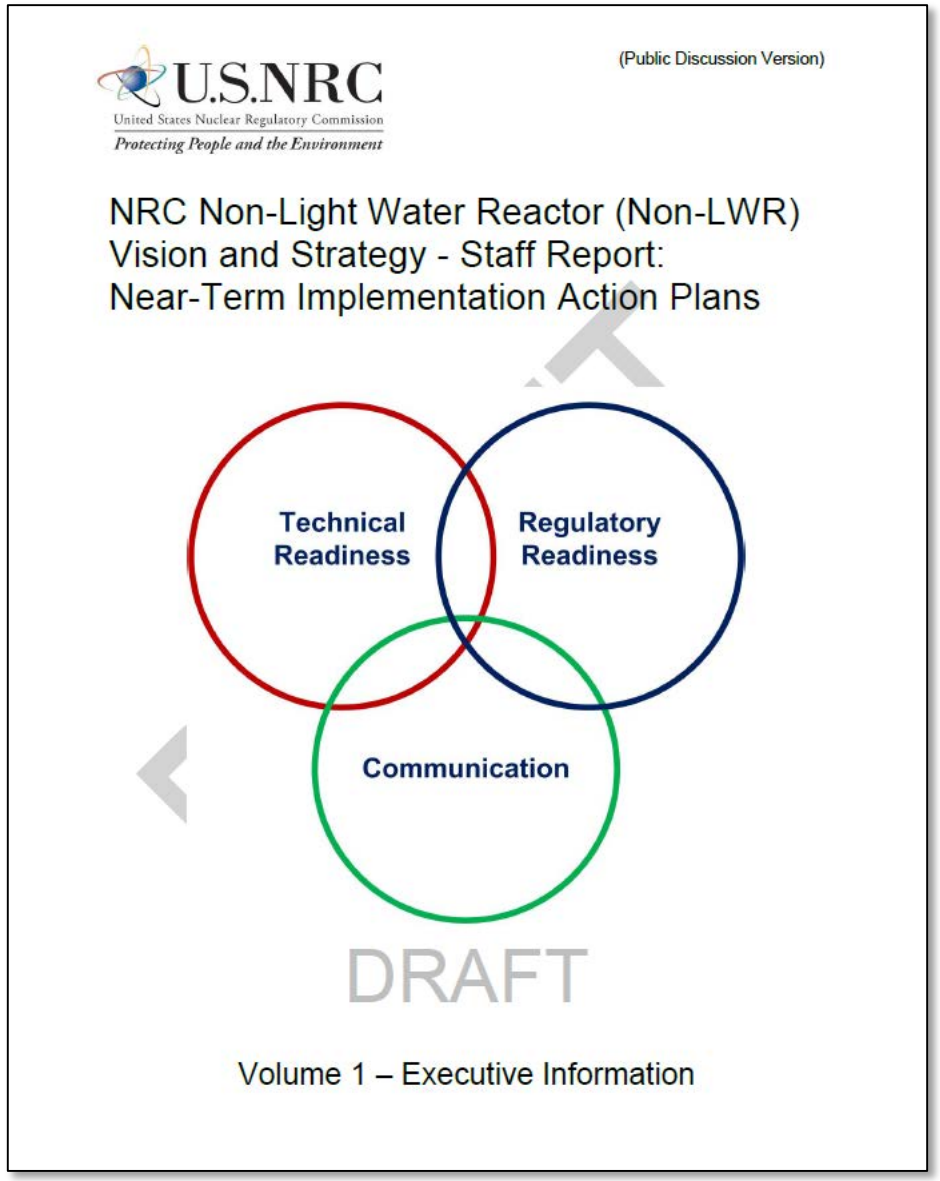
- Gateway for Accelerated Innovation in Nuclear (GAIN) provides industry a single access point to DOE/lab complex

- July 2016: EPRI co-hosted with NEI and GAIN technology-centric workshops, to focus, discuss and collect feedback on specific developer RD&D needs
  - **modeling and simulation (M&S) capabilities to support design and licensing was identified as a top cross-cutting need**

- December 2016 and January 2017: EPRI organized (with GAIN and NEI) two-part workshop on advanced reactor M&S Needs (https://gain.inl.gov/SitePages/Workshops.aspx)

What We've Heard from NRC

- **IAP Strategy #2:** The staff must have adequate computer models and other analytical resources to conduct its review of non-LWR designs in an independent manner
- Code assessment (*of QA for development, verification and validation*) remains paramount, accounting for:
  - Separate effects data
  - Integral effects data
  - Scaling
  - Model complexity (and understanding)



*NRC Non-Light Water Reactor (Non-LWR) Vision and Strategy - Staff Report: Near-Term Implementation Action Plans.

NRC Independence Does Not Preclude Cooperation

- Multiple code options can be considered, and there may be different code systems for various design types
- Independent confirmatory codes are preferred, but use of existing/common codes are under consideration (and may be essential)
  - in light of resource constraints and desire for timely reviews
  - as long as sufficient independence is maintained in their application
- High fidelity codes may reduce but will NOT eliminate the need for data from experimental testing

Challenges of Characterization and Testing

Examples from LWR Fuel Development

LWR Fuel Development and Qualification

- Fuel design specifications sufficient for manufacture
- Understanding of fuel properties and behavior under irradiation to define and constrain risks:
  - adequate safety for regulatory compliance
  - adequate performance and reliability for economic operation
- Demonstration that fuel manufactured according to specifications performs in accordance with licensing basis and operator requirements in real world environment

Timely, successful development and qualification require adequate testing and characterization data.

Experience with Advanced LWR Fuel Commercialization

- Development to deployment of current Nb-based Zr alloys (e.g., ZIRLO™ and M5™) spanned 20 ± 5 years

- Multi-cycle irradiations of lead test assemblies in commercial reactors span 5+ years (plus PIE, etc.)

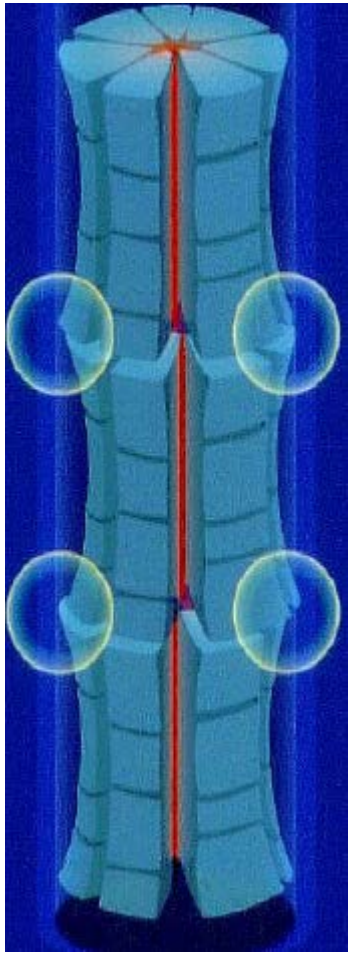
- Traditional approaches to fuel qualification and licensing assume compatibility with existing fuel and core designs
  - commercial reactors are not test reactors
  - compatibility issues with new materials and designs drive increased emphasis on test reactor irradiations

Lessons from Barrier Fuel Development*

- Development to deployment for BWR barrier fuel spanned 13 years (1973 – 1986)

- Key attributes of successful program included:
  - narrow problem definition: fuel failure from PCI
  - early introduction of concepts into power reactors
  - aggressive testing in terms of numbers and severity

- Access to testing, irradiation and post-irradiation examination facilities was paramount

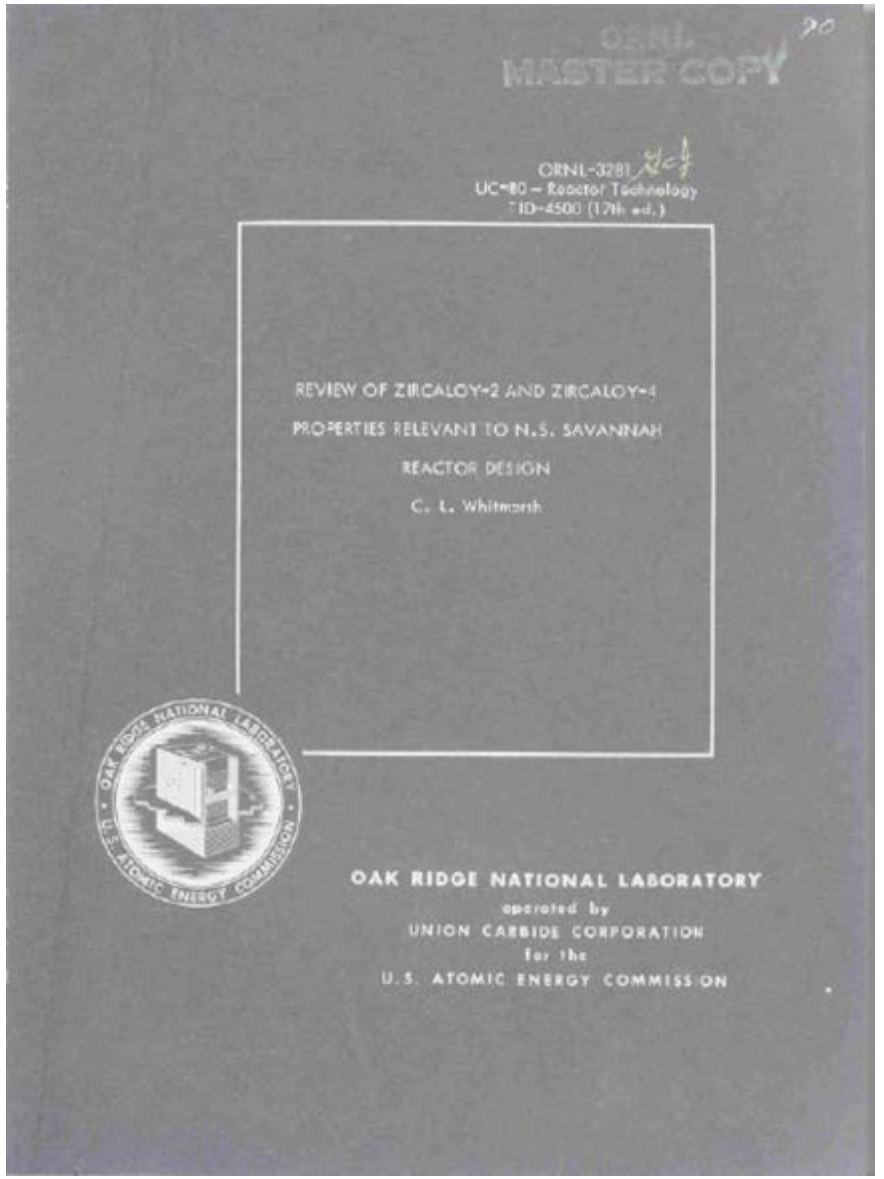


All but one of six test reactors used during development are now shut down.

*Example courtesy of J.S. Armijo, EPRI/INL/DOE Joint Workshop on Accident Tolerant Fuel, Feb. 2014

Commercial Operation is Just the Beginning…

- After new fuel, materials, components and systems enter commercial service, new data needs continue to arise
  - testing continues on Zry-2/4 after > 5 decades of service
  - new conditions and unanticipated issues lead to new questions
- Need for model/code development and testing data continues throughout product lifecycle



There is Hope (?!?)…Harnessing Innovation for Nuclear

(Some things have improved since the dawn of commercial nuclear power!)

- Modeling and simulation
- Materials and manufacturing

Image: Boeing

Image: Bill Carey

Value from rapid virtual prototyping in aerospace: elimination of design errors and dead ends through deliberate, integrated use of modeling and simulation.

Opportunities Through Engagement and Leveraging

Leveraging Existing Models/Codes and Data

- Consider use of existing modeling and simulation capabilities (recognizing different intent of design vs. confirmatory codes)
  - "legacy" and new codes, platforms (NEAMS, CASL)
  - university-based R&D (NEUP)
  - industry codes and tools

- Access to and consideration of experimental and operational data for many designs
  - from international experience
  - from past and ongoing US government sponsored R&D

Leveraging via Engagement and Collaboration

- NEI Advanced Reactor Working Group
  - NEI Advanced Reactor Technology Task Force
  - Industry-led technology working groups (MSR, FR, HTGR)
- DOE Gateway for Accelerated Innovation in Nuclear (GAIN)
- Standards Development Organizations (ASME, ANS)
- EPRI via existing Memorandum of Understanding with NRC/RES and DOE/NE

Together…Shaping the Future of Electricity