Enhanced Accident Tolerant Fuel (EATF)

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Technology advances can further enhance nuclear safety systems to address FUKUSHIMA type accidents in existing LWR design bases

EATF plays a part by improving margin

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EATF's role in enhancing margin

- **No technology will protect a reactor core in a complete loss of cooling scenario**
  - **Loss of the heat sink will result in the fuel temperature rise**
- **EATF should seek to delay or limit zirconium oxidation and damage to the fuel integrity during accident conditions**
- **Recognize that EATF must be economically competitive**
  - **Cannot divorce the fuel from the reactor**

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DOE Project Aim

- **Within 10 years deploy Lead Test Assemblies (LTAs) into an operational US light water reactor (LWR)**
  - **The nuclear industry is risk averse and so modifications to the fuel design will be incremental**
  - **The 10 year window and the risk adverse nature of the industry will limit the technologies that can be deployed**

- **Additional advances in EATF design after 10 year window should also be considered**

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Structure of a Fuel Assembly

- **In current LWR fuel design a large percentage of the Zr is used as the structural material supporting the rods**
  - **BWR ~ 30 %**
  - **PWR ~ 17 %**
- **Any technology that seeks to protect or replace the Zr must be capable of protecting the rods, grids and other structural components**

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Technology Considerations for EATF

- New clad and structural material
- Improved thermal characteristics of the pellets
- Coatings on the fuel assembly
- Combination of the above

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Industrial presence: Fuel

Richland, WA - US

- Fuel Manufacturing plant, Fuel Design

Fuel Manufacturing: 4 European sites

- Romans, Pierrelatte - France
- Lingen, Karlstein - Germany

Zirconium Manufacturing: 6 European sites

- Jarrie, Ugine, Rugles, Montreuil-Juigné, Paimboeuf - France
- Duisburg - Germany

Ulba -Kazakhstan

- Project of 1 JV* in Fuel Manufacturing: IFASTAR

* JV : Joint Venture

Other sites: 4

- Fuel Design, support functions: Lynchburg (Virginia) - US
- Fuel Design, european support functions, Lyon - France ; Erlangen - Germany
- Head office, Paris - France

China & Japan

- 2 JV* in Zirconium Manufacturing: CAST, ZP, Shangai - China / Shimonoseki - Japan
- 1 JV* in Fuel Manufacturing: MNF, Tokai - Japan

* JV : Joint Venture

16 industrial sites in Fuel activity: requiring optimization in the current context market

* JV : Joint Venture

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AREVA Team Members

- University of Wisconsin
  - 3 Enhanced Coatings
- University of Florida
  - SiC Fibers
  - Chromia doped fuel
  - Chromia Doped Fuel + SiC Fibers
- Savannah River National Laboratory
  - 3 Coatings
- Utility Partners
  - TVA and Duke to define user needs
  - EPRI to offer a Molybdenum Alloy for evaluation
- AREVA
  - Nano-particle coating on fuel rod
  - Chromia doped fuel assemblies in US reactor

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The AREVA team construct is balanced

Research

Technology

Fuel Vendor

Industrial

Utilities

Users

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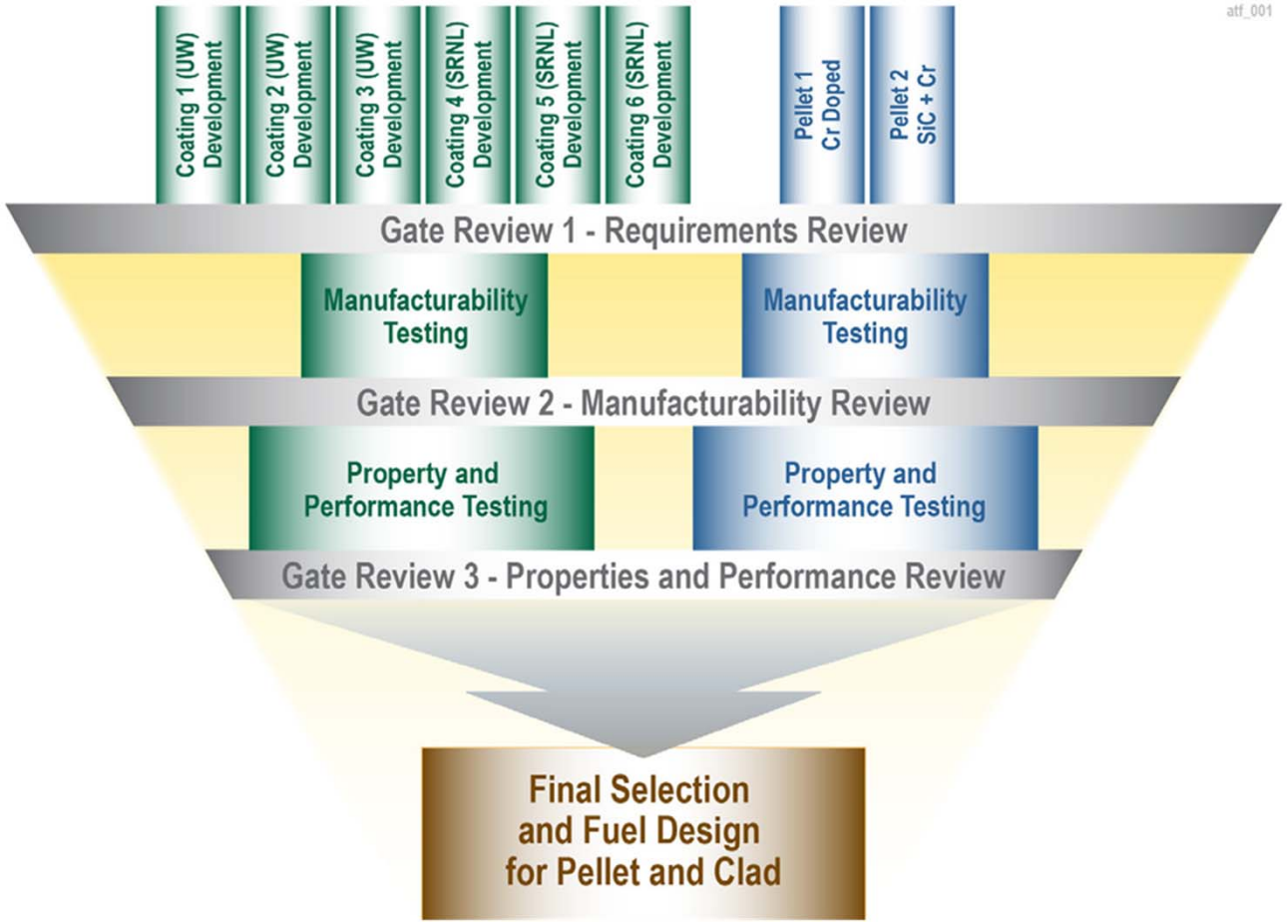
Development Process



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Wide range of technologies

- **Coatings**
  - SRNL developing “MAX Phase” materials and an enhanced surface treatment for zirconium. Example: Ti2AlC
  - UW developing direct deposit of metals and oxides on Zr clad using laser process
  - AREVA investigating use of nano-particles dispersed along a fuel rod intimately connected with the base normal crystalline zirconium alloy using various deposition techniques
- **Claddings**
  - EPRI investigating Molybdenum alloy materials to reduce clad reaction with steam in accidents
- **Pellets**
  - UF developing pellets with cromia dopants and SiC whiskers to improve thermal conductivity and fission gas retention. Spark plasma sintering process expected to reduce sintering costs

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Phased Approach

- **Phase 1: Discovery Phase** **2014**
  - Consider ideas and options promote innovation
  - Conduct gate review to help down select best available technology
  - Start irradiation tests in Advanced Test Reactor (ATR) of best options
- **Phase 2: Design Phase** **~2019**
  - Synthesize ATR results and finalize design
  - Develop licensing strategy to deploy LTAs to commercial reactor
- **Phase 3: Manufacture LTA's** **~2022**

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ATF in France

- AREVA involved in the evaluation of potential alternative nuclear fuel cladding materials
- Research conducted by CEA on enhanced safety margin materials
  - Steam oxidation resistant coatings on Zr-base cladding tubes
  - SiC-SiC claddings (Sandwich)
- Through bilateral contract, tripartite agreement (CEA-AREVA-EDF) or government funded project (ANR- MHYRACLE)
  - Presentation of Marion Le Flem (CEA)

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Conclusion

- **It is our responsibility to assure technological enhancements are applied to limit FUKUSHIMA type events**
  - **Industry stakeholders demand a critical review of available enhancements to nuclear safety**
- **EATF can play a role in these enhancements**
  - **Research should be conducted for incremental changes to LWR fuel that promote EATF characteristics**
  - **10 year window is embraced**
- **Cost for licensing, testing and fabrication of LTAs could be prohibitively expensive for any one vendor**
  - **Partnership with government and fuel vendors similar to the historical development of zirconium alloy clad**

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Thank you for your attention!

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