Accident Tolerant Fuels

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April 22, 2013

Accident Tolerant Fuel became a major focus area after Fukushima

- U.S. DOE fuel development program was exploring the development of next generation of LWR fuels enhanced performance.
  - Increased burnup – reduced waste volume
  - Increased reliability – reduced failures
  - Higher power density – power upgrades
- After the unfortunate events in Fukushima (March 2011) , the U.S. congress directed the DOE to focus efforts on development of fuels with enhanced accident tolerance.
- Accident Tolerant Fuel development program is being implemented as a collaborative effort among National Laboratories, Industry and Universities within the U.S.
- Due to the nature of the problem, International collaborations can also be beneficial.

Major attributes of accident tolerant fuels are associated with the behavior of fuel and cladding at high temperatures.

Fuels with enhanced accident tolerance are those that, in comparison with the standard UO_2 – Zircaloy system, can tolerate loss of active cooling in the core for a considerably longer time period (depending on the LWR system and accident scenario) while maintaining or improving the fuel performance during normal operations.

To demonstrate the enhanced accident tolerance of candidate fuel designs, metrics must be developed and evaluated using a combination of design features for a given LWR design, potential improvements and the design of advanced fuel/cladding system.

High temperature during loss of active cooling

Improved Reaction Kinetics with Steam
- Heat of oxidation
- Oxidation rate

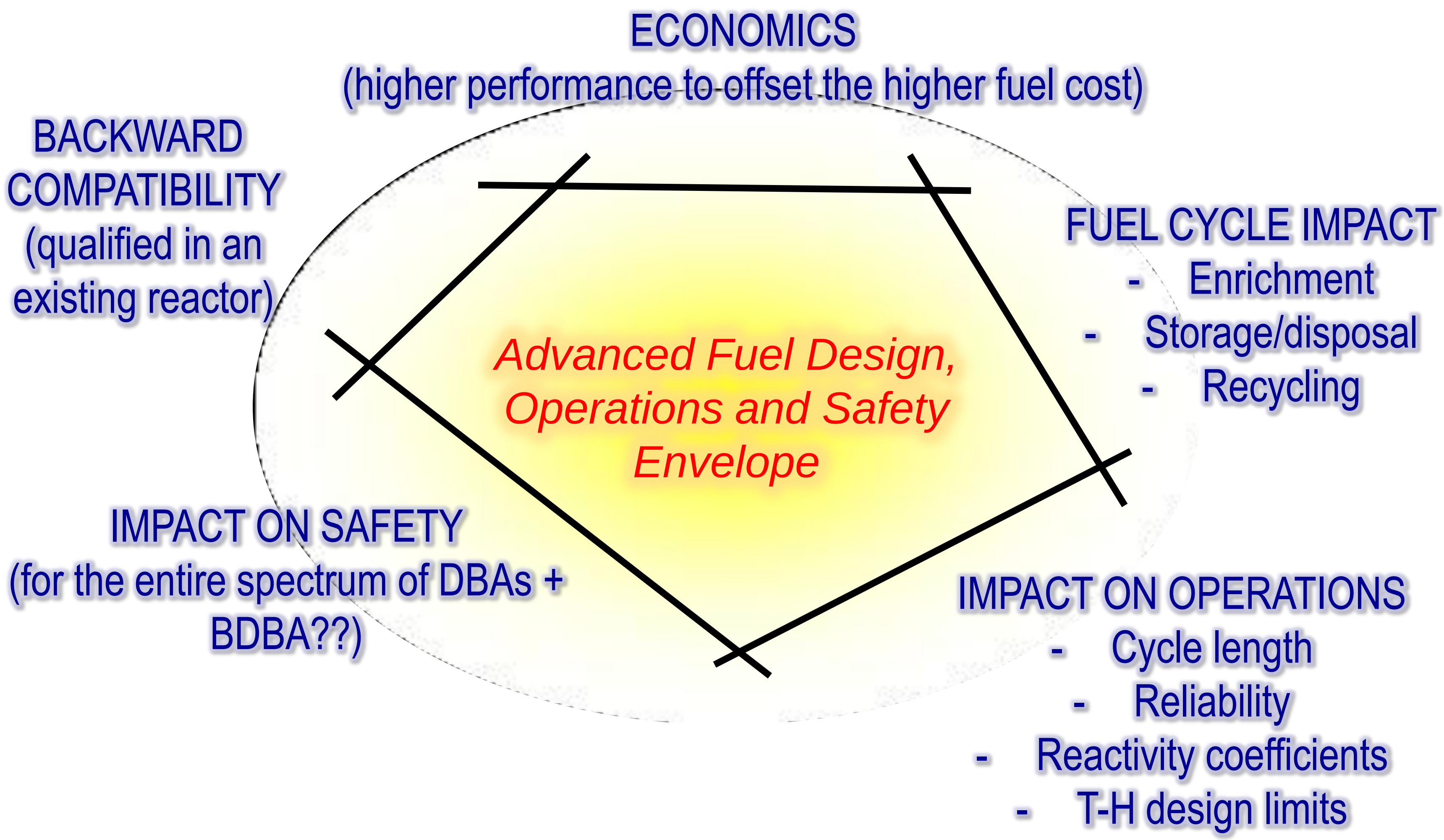
Slower Hydrogen Generation Rate
- Hydrogen bubble
- Hydrogen explosion
- Hydrogen embrittlement of the clad

Improved Fuel Properties
- Lower operating temperatures
- Clad internal oxidation
- Fuel relocation / dispersion
- Fuel melting

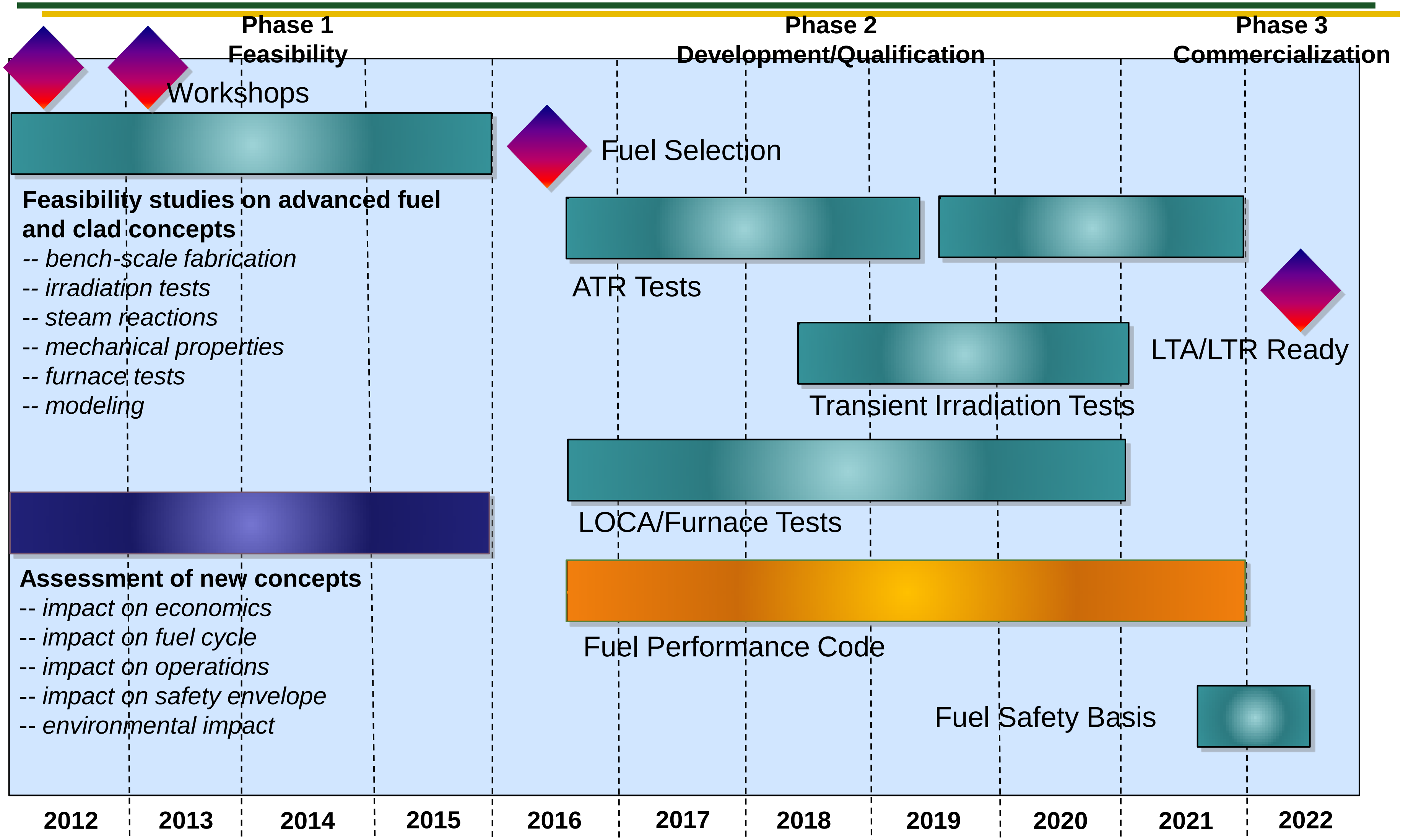
Improved Cladding Properties
- Clad fracture
- Geometric stability
- Thermal shock resistance
- Melting of the cladding

Enhanced Retention of Fission Products
- Gaseous fission products
- Solid/liquid fission products

The new fuel design must meet the LWR operational, safety and fuel cycle constraints



RD&D Strategy For Enhanced Accident Tolerant Fuels



Summary

- **There are a variety of related activities that currently use DOE-NE funding to support the development of advanced LWR fuels with enhanced accident tolerance**

- **Three FOA and three IRPs were awarded in FY 2012**
  - FOA led by experienced fuel manufacturers with deep teams
  - IRPs led by universities (with industry and national lab participation)
  - Work began in FY13 and continue for 2 (FOA) or 3 (IRP) years

- **National Laboratories, Industry, and universities are providing excellent thinking and recommendations on concepts for long-term consideration, as well as for near term program efforts (e.g. in support of Accident Tolerant mission)**

- **Program, university, and industry cooperation and collaboration is strongly encouraged and will help leverage related parallel activities in a constrained budget environment**

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U.S. DEPARTMENT OF ENERGY

Nuclear Energy

Summary of major FOA, IRP, and NEUP funded ATF projects

Lead Organization	Category – Major Technology Area	PI	Team Members	FOA, IRP, Lab, NEUP
AREVA	Protective materials, MAX phase, and high conductivity fuel	Paul Murray	SRNL, Univ. of Wisc., Univ. of Florida	FOA, NEUP
Westinghouse	SiC Cladding, U-Si-N Fuel,	Ed Lahoda	General Atomics, MIT, U of Wisconsin, EWI, INL, LANL, TAMU	FOA, NEUP
General Electric	Advanced Steels for Cladding	Raul Rebak	LANL, U. Michigan, Global Nuclear Fuels	FOA
University of Illinois	Modified Zr-based cladding	Brent Heuser	ATI Wah Chang, UIUC, UM, UF, UMAN, ORNL	NE-5 IRP
University of Tennessee	Ceramic Coatings for Clad	Kurt Sickafus	Westinghouse, Penn State, U. Mich., NNL	NE-5 IRP
Georgia Tech	U_3Si_2	Bojan Petrovic	Georgia Tech, U. of Michigan, Westinghouse, INL, U. of Idaho, U. of Tennessee, Virginia Tech, Morehouse College, Southern Nuclear	NE-7 IRP

U.S. DEPARTMENT OF ENERGY

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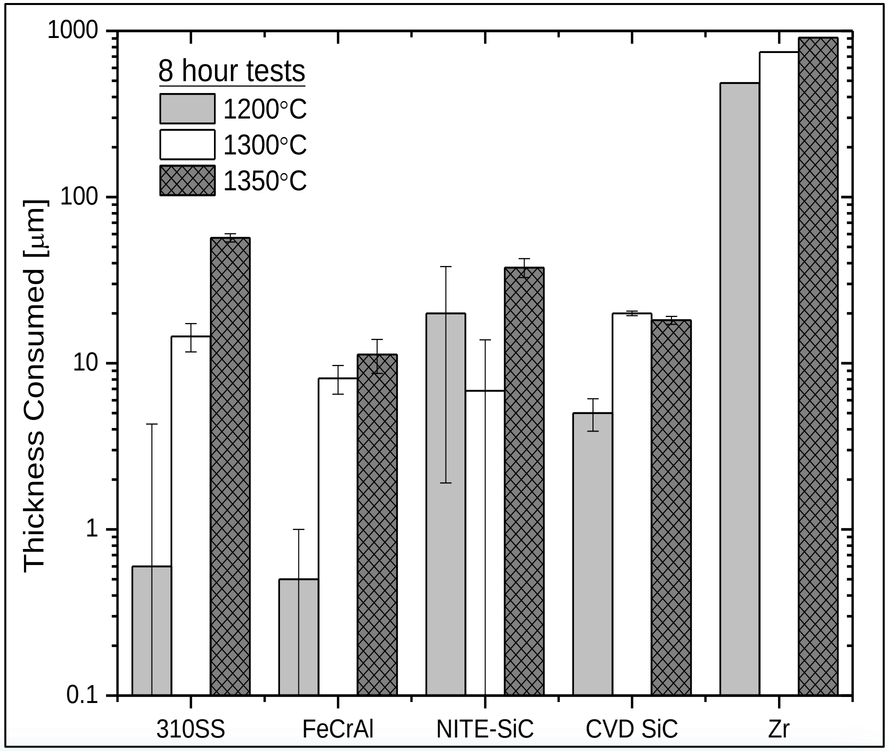
A primary program focus is on cladding materials with more benign steam reaction

- Advanced steels (e.g. FrCrAl)
- Refractory metals (e.g. Mo)
- Ceramic cladding (SiC)
- Innovative alloys with dopants
- Zircalloy with coating
  - SiC
  - MAX-phase ceramics



Each concept has some pros and cons across the spectrum of operating and transient conditions of interest. A systematic analytical and experimental evaluation is being performed during the feasibility studies.

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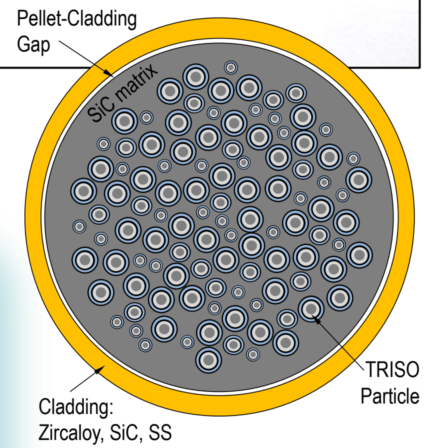
Some new fuel concepts also are being considered

- Higher density fuels (metal, nitride, silicide)
  - Higher thermal conductivity
  - Higher fissile density to compensate for neutronic inefficiency of some new clad concepts without increasing enrichment limits
- Oxide fuels with additives.
- Microencapsulated fuels
  - TRISO or BISO fuel dispersed in a ceramic or metallic matrix



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