Fuel Cycle Research and Development

FCRD Overview

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FCRD includes a variety of technologies looking at different fuel cycle options.
Develop the next generation of fuel cycle separation and waste management technologies that enable a sustainable fuel cycle, with minimal processing, waste generation, and potential for material diversion.

- The campaign strategy is based a sound balance between science and engineering
### Campaign Overview

Where we were, where we are and where we are going -

<table>
<thead>
<tr>
<th>Past (history)</th>
<th>Present (options)</th>
<th>Future (needs)</th>
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</thead>
<tbody>
<tr>
<td>Pu for weapons</td>
<td>UO$_x$ burning only</td>
<td>Pu MOX</td>
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<tr>
<td>PUREX</td>
<td>Once through</td>
<td>PUREX</td>
</tr>
<tr>
<td>Waste stored in tanks</td>
<td>Local SNF storage</td>
<td>Immediate waste treatment</td>
</tr>
<tr>
<td>Vent fission gasses</td>
<td>n/a</td>
<td>Vent or release fission gasses</td>
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<tr>
<td>Deferred vitrification</td>
<td>Deferred Fuel disposal</td>
<td>Glass for future disposal</td>
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<td></td>
<td></td>
<td>Capture and immobilize fission gasses</td>
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<td></td>
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<td>High performance waste forms/geologic disposal</td>
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### Focused Objectives

**Fundamental Science & Mod/Sim**
- Develop the next generation methods and tools for separations, waste form development, and waste form performance - fundamental science related to applied research

**Minor Actinide Sigma Team**
- Enabling technology for TRU recycle options from LWR fuel
- Develop cost effective technology ready for deployment

**Off-gas Sigma Team**
- Enabling technology for any recycle option (Tritium, Iodine, Krypton)
- Develop cost effective technology ready for deployment

**Advanced Waste Forms & Processes**
- Open disposal options with higher performance waste forms
- Develop cost effective technology ready for deployment

**Electrochemical Processing**
- Develop and demonstrate deployable and sustainable technology for fast reactor fuel reprocessing

**Fuel Resources**
- Develop cost effective method for passive sea water extraction
- Establish bounding cost for uranium resource
Novel metal organic frameworks (MOF’s) are being developed with the correct size and functionality to selectively capture Kr and Xe from air at near room temperature.

These materials are being developed for use in used nuclear fuel reprocessing plants.

There are obvious commercial applications for noble gas separation and sale.


The Fuel Cycle Research and Development Program has been developing waste forms for streams important to advanced fuel cycles:

- Alkali-alumino-silicate ceramics for high heat materials such as Cs
- Ceramics and glass ceramics for high halide streams
- These may be applicable to the Cs capture media and heavy brine wastes being collected as part of the Fukushima site cleanup

Model structure of $(^{137}\text{Ba}^{137}\text{Cs}^{133}\text{Cs})\text{AlSi}_2\text{O}_6$

Rare earth elements are used in electronics, magnets, catalysts, glass, metal alloys and ceramics – many of these uses have strategic and defense applications.

Currently about 95% of the world supply of rare earth elements comes from China.

The FCR&D minor actinide sigma team has extensive experience with 4f element separation and many of the technologies being developed could have application to separate or purify rare earth elements more effectively.
The program must address all three major elements of the campaign in a balanced way!

Next generation LWR fuels with enhanced performance and safety and reduced waste generation

Metallic transmutation fuels with enhanced proliferation resistance and resource utilization

Capabilities Development for Science-Based Approach to Fuel Development
- Advanced characterization and PIE techniques
- Advanced in-pile instrumentation
- Separate effects testing
- Transient testing infrastructure
Mission:
Develop advanced fuels and non-design intrusive reactor system technologies (e.g. instruments, auxiliary power sources) with improved performance, reliability and safety characteristics during normal operations and accident conditions.

Vision:
LWR fleet with enhanced accident tolerance providing a substantial fraction of the national clean energy needs.

10-year Goals
- Insert a LTA into a operating commercial reactor
- Demonstrate non-intrusive technologies that enhance safety (e.g. instrumentation with enhanced accident tolerance)
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.
Major issues for metallic fuel

- **Cladding** –
  - HT-9 possibly good up to 200 dpa
  - Radiation tolerance above 200 dpa

- **Fuel-Clad Chemical Interactions**
  - Diffusion barrier between the fuel and cladding
  - Ln getters within the fuels
  - Fission gas getters in the plenum
Major issues for storage/disposition

- **Disposition**
  - Container/cask materials resistant to environmental degradation in hundred thousand-year time frame

- **Dry storage**
  - Container/casks materials resistant to environmental degradation in hundred-year time frame
  - Remote/non-destructive monitoring technologies