U.S. DEPARTMENT OF ENERGY | Nuclear Energy

Studies and Future Perspectives for Reduction of Radioactive Wastes in the United States

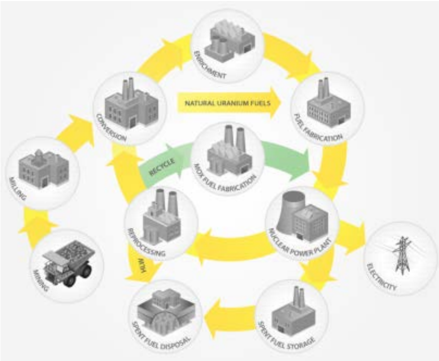
Dr. John W. Herczeg
Deputy Assistant Secretary for Fuel Cycle Technologies
Office of Nuclear Energy
United States Department of Energy

International Symposium on Present Status and Future Perspective for Reduction of Radioactive Wastes

17 February 2016

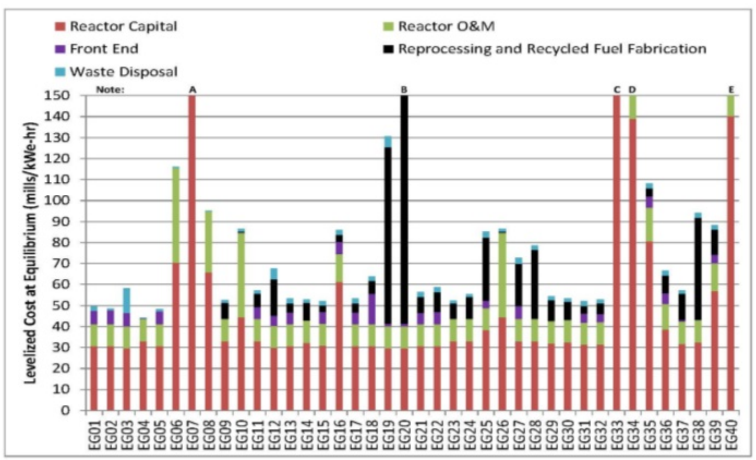
Overview

- **Basis for Research Paths**
- **Recent, Ongoing, and Future Studies**
  - Aqueous-Based Material Recovery and Waste Reduction
  - Electrochemical-Based Material Recovery and Waste Reduction
- **Safeguards and Monitoring Technologies**
- **Future Interests**
- **Summary**

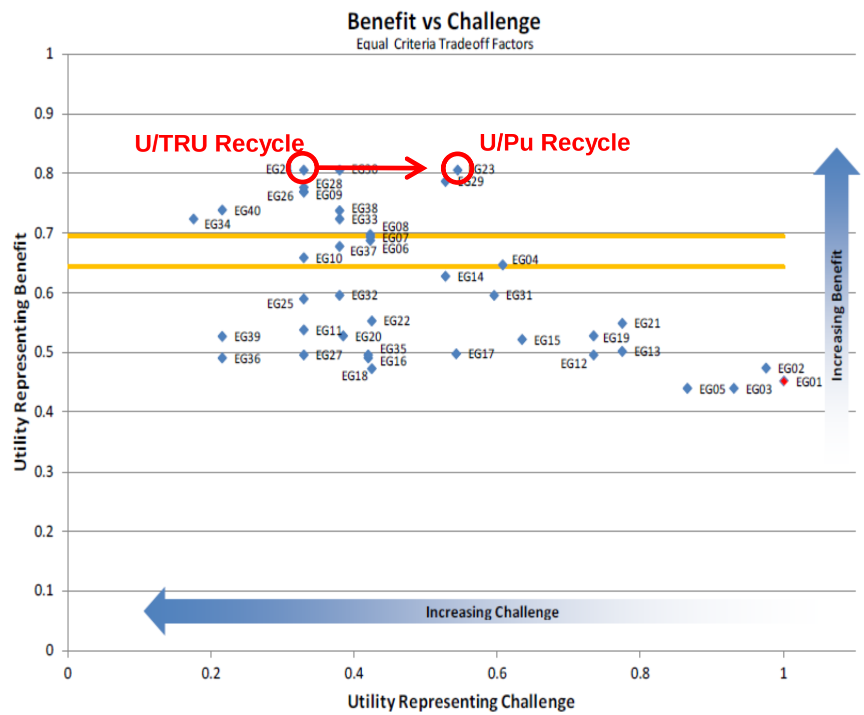


Basis for Research Paths

- **U.S. program has the flexibility to study & consider a range of fuel cycle options to understand benefits, limitations, and key issues for research.**
- **The program is moving forward with select R&D topics to reduce technical risk and uncertainty for future fuel cycle options.**

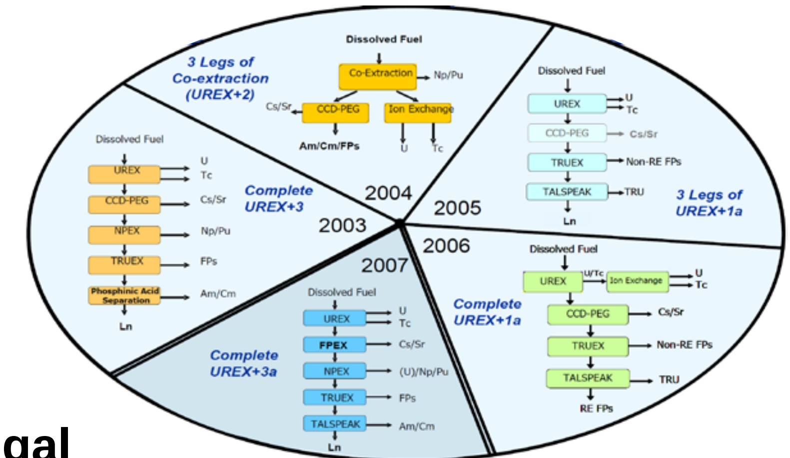


Evaluation and Screening of Nuclear Fuel Cycle Options
https://fuelcycleevaluation.inl.gov

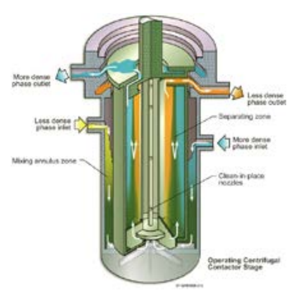


Recent Studies - Aqueous

- **The UREX+ family of processes were developed to avoid extraction of pure plutonium.**
  - Have the advantage of using well-known chemistry
  - Limitations from lifetime of acetohydroxamic acid (AHA)
  - Five laboratory-scale demonstrations with irradiated fuel completed in the 2003-2007 timeframe

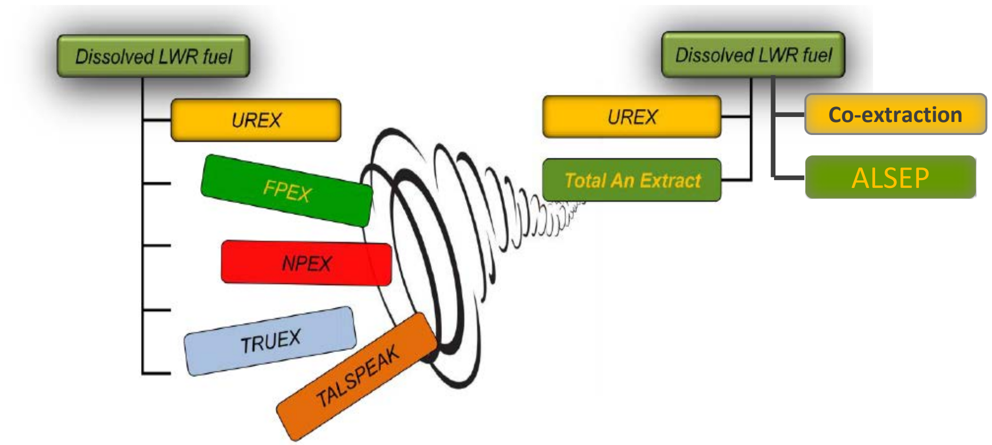


- **Development and demonstration of centrifugal contactors have provided enhancements.**
  - Contactors provide an alternative to conventional mixer-settlers and pulsed columns
  - High efficiency, short residence time, small space
  - Increased remote maintenance



Ongoing Studies for Aqueous Material Recovery

- **The current emphasis is to develop a simplified, robust method for advanced actinide separation.**
  - Develop cost effective technology ready for deployment
- **The two primary approaches being investigated involve selective complexation of An(III) over the Lns, and the oxidation of Am(VI) to enable a group actinide separation.**



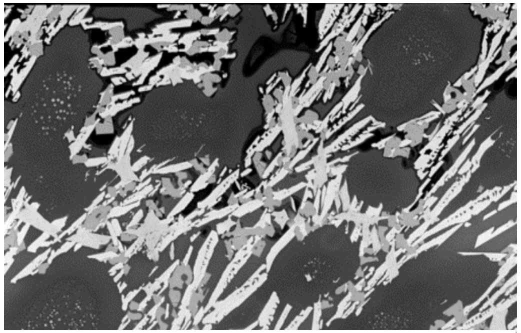
UREX^{+} 3a
2003-2008

Ongoing Studies for Aqueous Material Recovery

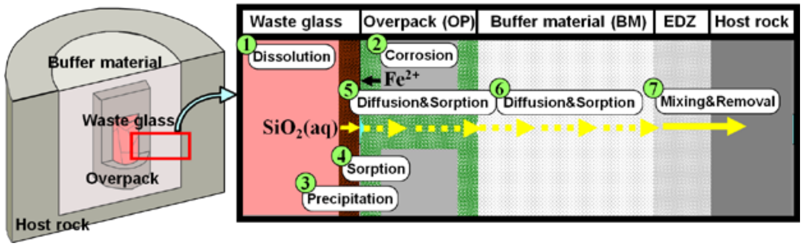
U.S. DEPARTMENT OF ENERGY
Nuclear Energy

Advanced Waste Forms and Characterization

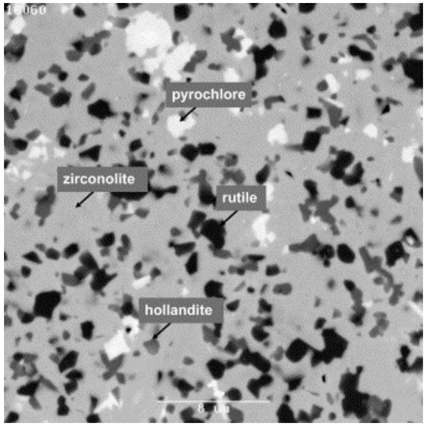
- R&D for material recovery includes the complete process cycle, including waste forms and behaviors
- Development of fundamental understanding of waste form performance under disposal conditions
- Development of improved processes
- Significant level of international collaboration



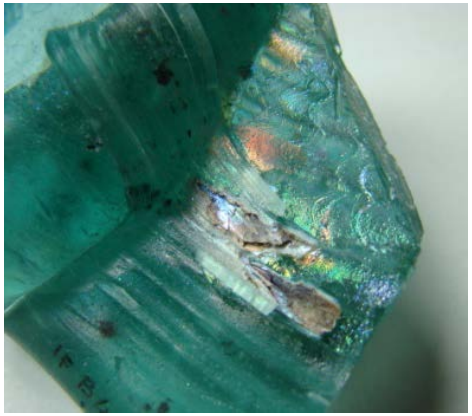
Electron Micrograph of Glass Ceramic



Waste package model representation from JAEA



ANSTO Synroc

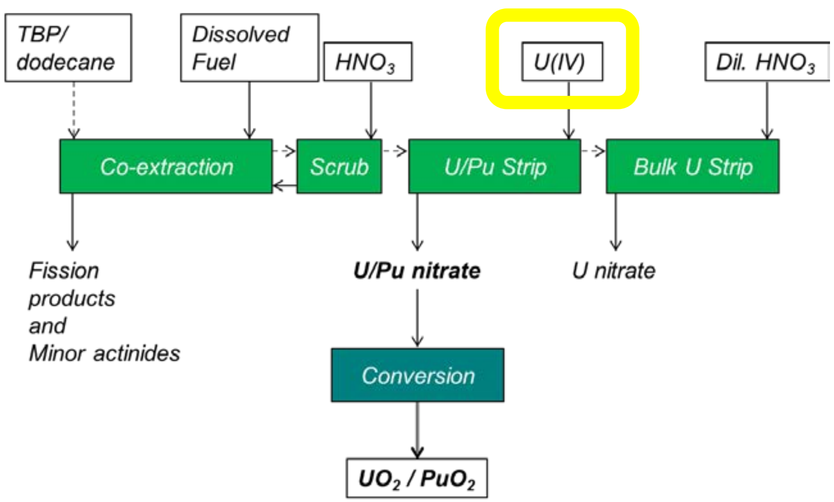


Glass from Iula Felix, ca 1800 y old

New Studies for Aqueous Material Recovery

Co-Decontamination Project (CoDCon)

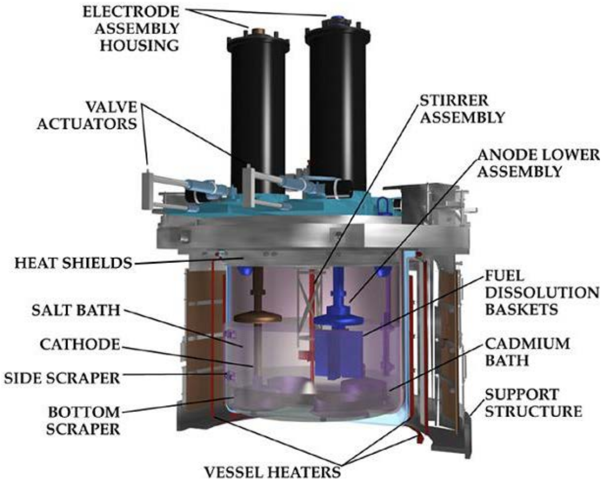
- Demonstrate a separation advanced separations process with irradiated nuclear fuel
- 30/70 plutonium/uranium MOX product
- Study of 4-year duration and beginning in 2016

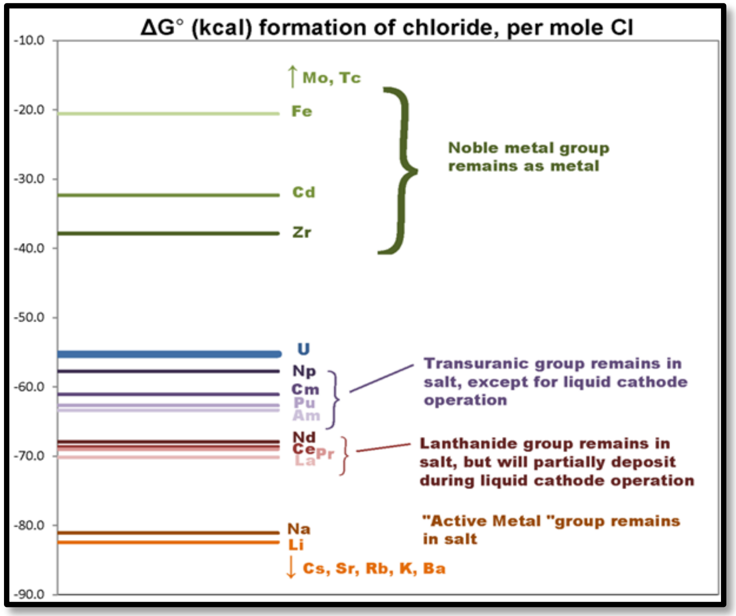


Recent Studies - Electrochemical

Electrochemical processing of metallic fuel from the Experimental Breeder Reactor-II (EBR-II)

- Molten salt-based process separates constituents based on electrochemical stability in the chloride phase
  - Low-enriched uranium product
  - Processes at ~10 kg scale

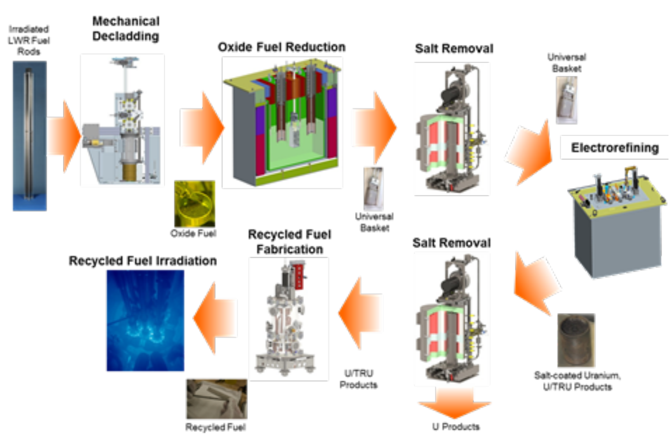


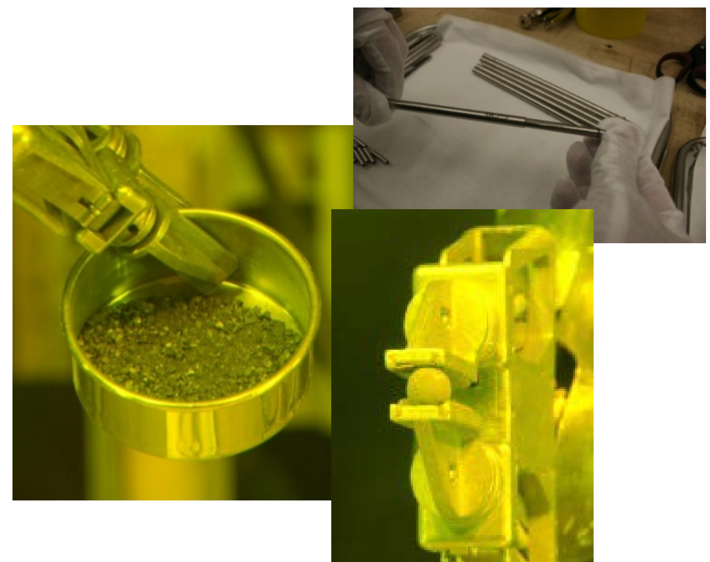


Ongoing Studies for Electrochemical Recycling

Joint Fuel Cycle Studies

- Assessment of the technical and economic feasibility and nonproliferation acceptability of electrochemical recycling and other options for managing used nuclear fuel
- Used commercial oxide fuel processed to generate metallic uranium and U/TRU products
- Strong R&D as well as demonstration component
- Started in 2011 with 10-year duration



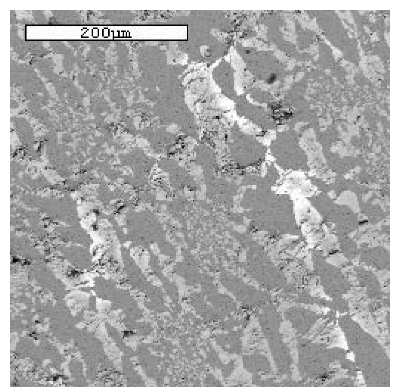


Recent Studies for Electrochemical Recycling

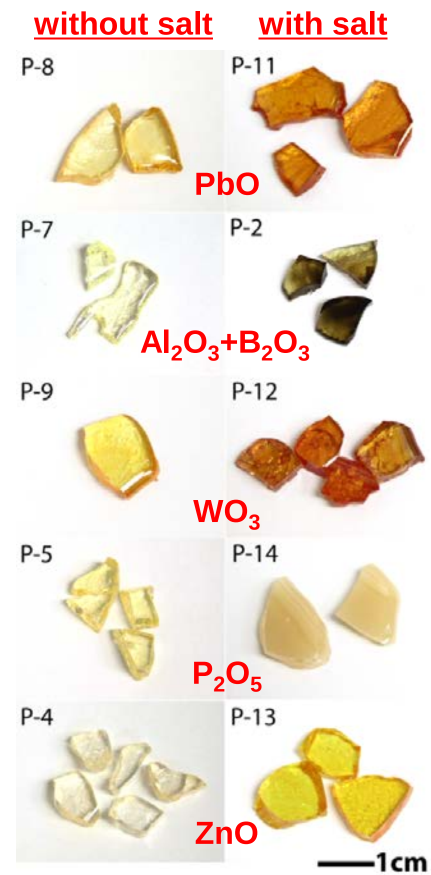
Development of advanced waste forms and processes tailored for electrochemical recycling processes

- Lead tellurite glasses
- Improved sodalite
- Zinc titanate
- Silica-alumina phosphate

Advanced sodalite synthesis



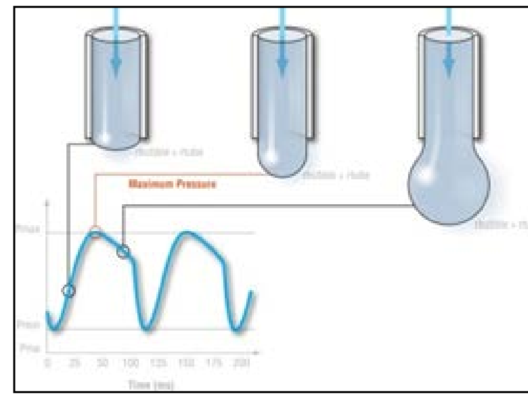
Waste forms for noble metals

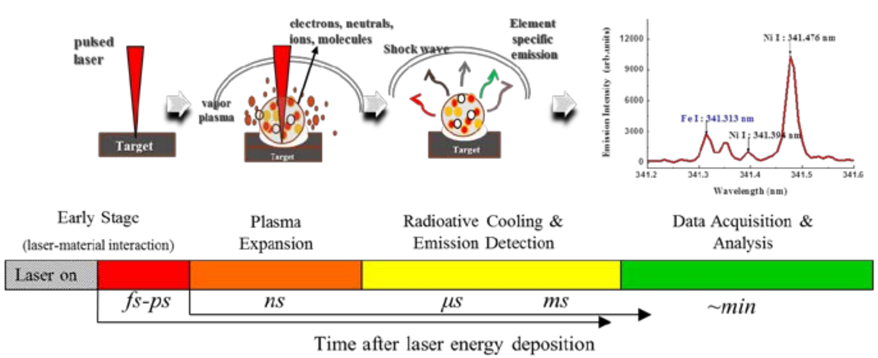


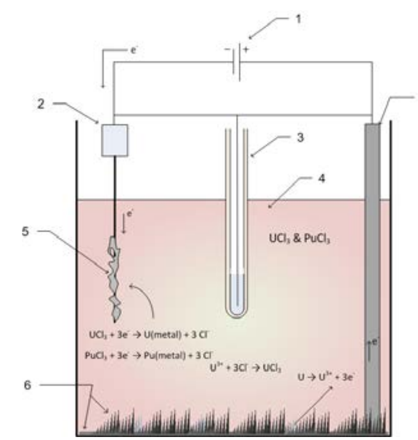
Tellurite glasses

Safeguards and Monitoring Technologies

- **Safeguards and monitoring technologies are important to all separations processes.**
- **Improvements to methods and technologies are needed.**
  - Laser-induced breakdown spectroscopy (LIBS) – near real-time composition information (Echem)
  - Triple bubbler – real time density, level
  - Voltammetry, actinide sensor for molten salts







U.S. DEPARTMENT OF ENERGY

Nuclear Energy

Potential Future Interests

Processing of core debris (Corium)

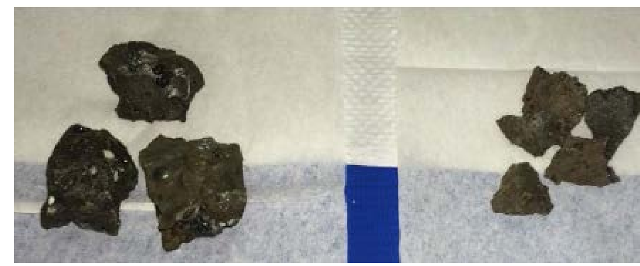
- Corium can be a complex mixture, but primarily comprised of UO_2, ZrO_2, and siliceous materials.
- Initial studies of corium-type materials indicated that dissolution can be challenging by aqueous processes. Electrochemical techniques may be an alternative.
- Some fission product chemistry may be modestly different in corium versus irradiated fuel, but not expected to be a significant issue.
- Presence of seawater chlorides should not significantly impact electrochemical process.

Simulated Corium Melt

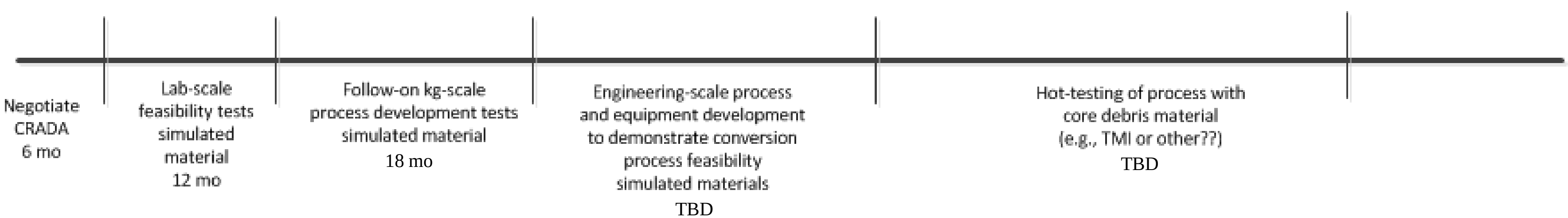
Component Oxides	Irradiated LWR Fuel	Simulated Corium In-vessel	Simulated Corium Ex-Vessel	Predicted Electroreduction Partitioning
Major (>10 wt%)				
UO_2	X	X	X	Cathode – metal
ZrO_2	X	X	X	Cathode – metal
SiO_2			X	
-				
Minor (1-5 wt%)				
Cr_2O_3		X	X	
CaO			X	Salt
Al_2O_3			X	Cathode – oxide
SrO	X	X	X	Salt
Trace (<<1 wt%)				
Fe_2O_3		X	X	Cathode – metal
MgO			X	Cathode - oxide
CuO		X	X	Cathode – metal
HfO		X	X	Cathode - metal
K_2O			X	Salt
MnO		X	X	Cathode – metal
Na_2O			X	Salt
NiO		X	X	Cathode – metal
Ta_2O_5		X	X	Cathode - metal
TiO_2		X	X	Cathode – metal
ZnO		X	X	Cathode – metal

Potential Future Interests

- Corium treatment via electrochemical processing methods is a potential approach, but requires experimental confirmation.
- Simulated and real materials potentially available for testing.



Corium to metal conversion process development timeline
(No separation of actinides from metal product)



Summary

- Robust R&D history in material recovery and reduction of radioactive wastes, in both aqueous and electrochemical technologies
- Ongoing studies investigate cutting-edge issues in separations technologies
- Future interest to investigate processing of corium-type materials