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Fuel Cycle Research and Development

Separations, Waste Forms, and Spent Nuclear Fuel Disposition Campaign Overview

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2010 Nuclear Energy University Programs Workshop

August 13-14, 2009

Salt Lake City, UT

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Campaign Organization

- **FCR&D Separations Campaign**
  - Jim Bresee, DOE-HQ Program Manager
  - Terry Todd, Separations Campaign Director, INL
    - *Kevin Felker, Campaign Deputy, ORNL*
- **FCR&D Waste Forms Campaign**
  - Sue Lesica, DOE-HQ Program Manager
  - Terry Todd, Waste Forms Campaign Director, INL
    - *John Vienna, Campaign Deputy, PNNL*
- **FCR&D Spent Nuclear Fuel Disposition**
  - Patrick Schwab, DOE-HQ Program Manager
  - Mark Peters, Spent Nuclear Fuel Disposition Campaign Director, ANL
    - *Peter Swift, Campaign Deputy, SNL*

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Mission Statements

- **Separations**
  - 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

- **Waste Forms**
  - Develop and demonstrate durable waste forms and processes to enable safe and cost-effective waste management as an integral part of a closed nuclear fuel cycle by establishing a fundamental understanding of behavior through closely-coupled theory, experiment, and modeling

- **Spent Nuclear Fuel Disposition**
  - Identify alternatives and conduct scientific research and technology development to enable storing and disposing of spent nuclear fuel and wastes generated by existing and future nuclear fuel cycles

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Separations Objectives

- Develop a fundamental understanding of used fuel separation chemistry through coupled theory, experimentation, and simulation
- Ensure that used fuel separation processes are safeguardable through a comprehensive approach that includes technology, transparency, accountability and physical protection
- Develop and demonstrate processes which meet specifications for product recycle and reuse, reduce waste, and convert liquid waste to durable solid waste
- Create validated modeling and simulation tools to predict separations process performance in a laboratory and industrial environment, in order to facilitate development and future deployment
- Demonstrate safe, economically-viable, industrially-deployable, and licensable processes to allow future recycling of used nuclear fuel

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Waste Forms Objectives

- Develop robust and cost-appropriate waste and storage forms through testing and modeling
- Increase technological readiness of waste processes through analyses, testing, and demonstrations
- Develop fundamental understanding of waste form performance through coupled theory, testing, and modeling to support waste form qualification
- Create validated modeling and simulation tools and predict waste form characteristics and performance in relevant disposal environments and quantify their uncertainties
- Conduct and inform analyses of waste management options to derive waste form R&D requirements
- Integrate waste management into development and optimization of separations processes and the closed fuel cycle system, both domestically and internationally
- Facilitate the reuse of materials through market/application identification, requirements development, and reuse technology development

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Spent Nuclear Fuel Disposition Objectives

Near-Term Objectives

- **Inform external evaluations of spent fuel disposition alternatives**
- **Collate Technical Bases for geologic disposal**
- **Provide top-level model development to evaluate disposal system performance in a variety of generic disposal system concepts**
- **Collate Technical Bases for storage of spent fuel, high-level waste, and low-level waste**
- **Identify R&D opportunities related to long-term storage of spent fuel, HLW, and separated products**
- **Conduct trade studies to inform policy development**

Long-Term Objectives

- **Evaluate security systems, novel storage facilities, and operational concepts**
- **Develop a predictive capability for performance of disposal options for a range of fuel cycle alternatives**
- **Develop process-level models for a variety of disposal environments and predictive capability to evaluate storage concepts**
- **Improve contaminant dispersion modeling capability**
- **Develop systems for different fuel types (MOX, advanced reactor fuel)**
- **Establish techniques for burnup credit**

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FY2010 Separations Focus Areas

- **Continue research and development on "evolutionary" technologies**
  - Maintain continuity and continue to mature technology for nearer-term implementation – work on elements that are common to many approaches
- **Expand Sigma Team concept to include:**
  - Am or Am/Cm separations (continue this effort)
  - Off-gas capture and immobilization (new Sigma team)
- **Initiate research into "transformational" technologies**
- **Expand research into understanding fundamental properties of separation processes and developing reaction mechanisms**
  - Thermodynamics, kinetics, radiation chemistry, etc
  - Develop new fundamental research capabilities and methods
- **Couple theory, experimentation and modeling to develop predictive capabilities**

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FY2010 Waste Forms Focus Areas

- **Continue development of alloy and glass waste forms to maintain continuity and continue to mature technology for nearer-term implementation**
- **Expand development of electrochemical process waste forms**
- **Integrate off-gas immobilization research with research into capture methods in a new Sigma Team**
- **Initiate significant research activities in alternative waste forms**
  - High density, natural analogs
  - Higher durability due to tayloring waste form structures to specific radionuclide immobilization and geologies
- **Expand research into understanding fundamental properties of waste forms and corrosion mechanisms**
  - Interfacial science, transport phenomena, radiation-induced defects, etc
  - Develop new fundamental research capabilities and methods
- **Couple theory, experimentation and modeling to develop predictive capabilities**
  - Essential for time-scales that waste forms must perform

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FY2010 Spent Nuclear Fuel Disposition Focus Areas

- **Analyses and Trade Studies**
  - Rapid Response
  - Legal and Regulatory Framework Alternatives
  - Storage Analyses and Trade Studies
  - SNF/HLW Disposition
  - LLW Disposition
- **Technical Evaluations and Science Based Predictive Tools**
  - Features, Events, and Processes (FEP) Categorization and Cross-Map
  - Disposal Systems Evaluations and Tool Development
  - R&D Roadmap and Workshop
  - Initiate Modeling and Simulation, Experiment, and Testing program

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Separations Focus Areas for University Proposals

- Investigate fundamental interfacial electrochemistry of actinides and fission product elements important in the fuel treatment process; for example, determination of thermodynamic properties in process relevant molten salts (e.g., LiCl, LiCl/KCl) or characterization of kinetics and mass transport properties of important species in molten salts
- Develop new and innovative methods for the capture and immobilization of volatile fission products (iodine, tritium, krypton and carbon-14) from spent fuel off-gas (during shearing and dissolution)
- Develop novel separations methods for gas reactor (SiC or TRISO) fuels.
- Investigate transformational separations technologies.
- Fundamental understanding of An(III) separation from Ln(III) elements.

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Waste Forms Focus Areas for University Proposals

- **Develop a fundamental understanding of waste form stability over geologic time scales, including effects of various stresses such as elevated temperature, the decay of radionuclides into other elements, high radiation fields and other varying environmental conditions, leading to the prediction of radionuclide release over millennia.**
- **Develop and test the next generation of nuclear waste forms capable for radionuclide immobilization, with simple remote fabrication capability and predictable performance.**

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Spent Nuclear Fuel Disposition Focus Areas for University Proposals

- **Development of innovative used fuel and nuclear waste storage concepts capable of at least 100 years duration**
- **Development of advanced methods for evaluation of the performance of waste storage forms, in a variety of geologic media and over geologic time scales, of used nuclear fuel and specific waste forms for fission products, including iodine, krypton, tritium and carbon-14.**
- **Development of advanced engineering materials for use in waste packages in a variety of geologic media.**

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Grand Challenges for Focus Areas

- **Separations**
  - Single-step separation process for Am or TRU
  - Near-zero radioactive off-gas emissions (an order of magnitude lower than risk based regulations)
- **Waste**
  - Reduce waste volume of HLW, LLW, GTCC, by an order of magnitude
  - Increase durability of HLW and LLW by an order of magnitude over current reference
- **Spent Nuclear Fuel Disposition**
  - Develop storage and disposal systems resulting in near-zero radionuclide releases