BASIC SCIENCE RESEARCH TO SUPPORT THE NUCLEAR MATERIAL FOCUS AREA

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ABSTRACT

The Department of Energy's (DOE's) Office of Environmental Management (EM) is responsible for managing more than 760,000 metric tons of nuclear material that is excess to the current DOE weapons program, as a result of shutdown of elements of the weapons program, mainly during the 1990s. EM-owned excess nuclear material comprises a variety of material types, including uranium, plutonium, other actinides and other radioactive elements in numerous forms, all of which must be stabilized for storage and ultimate disposition. Much of this quantity has been in storage for many years. Shutdown of DOE sites and facilities requires removal of nuclear material and consolidation at other sites, and may be delayed by the lack of available technology.

Within EM, the Office of Science and Technology (OST) is dedicated to providing timely, relevant technology to accelerate completion and reduce cleanup cost of the DOE environmental legacy. OST is organized around five focus areas, addressing crucial areas of end-user-defined technology need. The Focus Areas regularly identify potential technical solutions for which basic scientific research is needed to determine if the technical solution can be developed and deployed. To achieve a portfolio of projects that is balanced between near-term priorities driven by programmatic risks (such as site closure milestones) and long-term, high-consequence needs that depend on extensive research and development, OST has established the Environmental Management Science Program (EMSP) to develop the scientific basis for solutions to long-term site needs. The EMSP directs calls for proposals to address scientific needs of the focus areas.

Needs are identified and validated annually by individual sites in workshops conducted across the complex. The process captures scope and schedule requirements of the sites, so that focus areas can identify technology that can be delivered to sites in time to complete site cleanup. The Nuclear Material Focus Area (NMFA) has identified over two hundred science and technology needs, of which more than thirty are science needs.

The science needs identified by end users of the NMFA fall into three technical areas, with additional more generic needs in crosscutting areas. The first of these encompasses needs for better understanding of chemical processes applied to current or expected material streams being processed for stabilization and storage at various sites. Science needs in the chemical processing area fall under the scope of the Processing product line, but also include needs from the Spent Fuel product line. The second area constitutes needs associated with understanding gas generation likely to occur within storage containers for nuclear material, including spent nuclear fuel, as well as metal, oxide and other compound forms of plutonium, uranium and other actinides. Science needs in gas generation come from the Stabilization product line, the Packaging and Transportation product line and the Spent Fuel product line. The final technical category consists of needs in a variety of material science arenas, ranging from accident testing design and implementation and welding technology to short- and intermediate-term corrosion to long-term degradation processes. Science needs in the Material Science area come from the Long Term Storage product line, the Depleted Uranium product line, and the Spent Fuel product line. Sites have also identified a need for technical basis data, which may cover a variety of research areas, to support the

development of standards for stabilization, packaging, transportation and long-term storage of nuclear material, including spent fuel, neptunium, and americium. Additional science needs have been identified within the depleted uranium product line in the area of enabling alternative disposition paths (besides disposal) for depleted uranium.

Crosscutting programs within OST have offered several basic science research areas to be considered. The Robotics program has identified needs for advances in automated systems that potentially affect all areas of nuclear material handling. The Characterization, Monitoring, and Sensor Technology program has identified needs for sensors for gas constituent identification and pressure measurement over the operating range of sealed storage containers. The Efficient Separations Program has identified needs in optimized precipitation in solutions stabilization and processing, and in actinide flow sheet development for new processes within existing facilities and equipment.

Within each of its six product lines, the NMFA has validated a number of needs, identified across the DOE complex, that require an understanding of new basic science. This research is anticipated to lead to new technologies to solve these difficult problems. These advances are expected to reduce costs, schedules, and risks associated with the disposition of materials related to the NMFA. Prioritization of these needs and identification of crosscutting needs is currently underway as part of the NMFA planning process. It is anticipated that a number of these areas of basic science will be addressed in an upcoming EMSP call directed toward the NMFA needs.

INTRODUCTION

Nuclear Material in the DOE Environmental Management Program

EM is responsible for managing nuclear material that is excess to the current DOE weapons program. It includes material transferred to EM as a result of shutdown of elements of the weapons program during the 1990s. The rapid shutdown of many processes during that time left many materials without a path forward to ultimate disposition. Much of this material is subject to bilateral treaties, and the development of technology to address the needs of DOE sites must take into account these treaty obligations. Research and development effort on this material is also relevant to the resolution of proliferation and national security concerns arising from similar quantities of material in Russia and other states of the former Soviet Union, although this is not a direct part of the OST mission. EM-owned excess nuclear material comprises a wide variety of different material types, including uranium, plutonium, other actinides and other radioactive elements in numerous forms. These are summarized in Table I.

All of these material types must be stabilized for storage and ultimate disposition. Much of this quantity has been in storage in various forms for many years. A number of recommendations of the Defense Nuclear Facilities Safety Board (DNFSB) have identified the need for stabilization of these materials, and have identified a need for research and development to support this stabilization (*DNFSB 1994, 1997, 2000, and DOE 1995, 1997a, 2001*). The need to reduce the environmental footprint of the DOE has driven shutdown of several sites and facilities, and plans exist for additional closures. Shutdown of DOE sites and facilities requires removal of nuclear material and consolidation at other sites. In some instances, the lack of available technology threatens to delay closure of sites and facilities.

Basic Science and the Office of Science and Technology Mission

The OST is dedicated to providing timely and relevant technology to accelerate the completion and reduce the cost of the cleanup of the environmental legacy of the DOE complex. OST's focus is on the rapid deployment of technology available now or in the near future to meet priority needs of the sites. OST is organized around five Focus Areas, each addressing a crucial area of EM technology needs. In the course of identifying and validating needs, the Focus Areas, in conjunction with the end-users, commonly identify potential technical solutions for which crucial scientific principles are poorly understood and data are lacking. Thus basic scientific research is required to determine if the technical solution can be developed and deployed.

Table I. Quantities of Nuclear Materials in EM custody

Nuclear Material	Number of Sites	Quantity (metric tons)	Comments
Depleted U	34	760,000	Most as depleted UF_6 (DUF_6) at gaseous diffusion plants at Oak Ridge (K-25), Paducah, Portsmouth
Lightly enriched U (LEU)		4,700	Largest blocks as alloyed & unalloyed metals & oxides, mainly at Hanford & Fernald, and UF_6 at Paducah. Additional 5,300 MT designated as programmatic
Excess highly enriched uranium (HEU)	10	174	Withdrawn from national security programs, half as metal and half as oxides, reactor fuel, compounds, unirradiated fuel & targets, etc.
U^{233}	5	1.9	Bulk at INEEL (irradiated and unirradiated fuels) and ORNL (recovered oxide)
Pu	8	100	
Th	19	100	
Additional quantities Pu^{238}, Np^{237}		Classified	
Other Isotopes (Am, Cm, Bk, Cf, Cs, Sr)		Lesser Quantities	Over 50,000 items with over 100 million Curies of radioactivity.
Spent Nuclear Fuel	4	~2,500	Includes ~120 metric tons not yet in inventory, but expected to be received over the life of the EM program.

OST has described the path from primary scientific research to technology deployment as consisting of a sequence of stages separated by "gates" (points at which technical review can support decisions to proceed or terminate a technology project – see Table II). In the terminology of the OST gate model (*DOE 1997b*), a technology is at Gate 0 when significant primary research is required to define the technical solution. The expectation is that several years of research and development will be required for a technology to be developed to the point that it can be successfully demonstrated (Gate 5) and deployed (Gate 6). Because of the longer development horizon, site needs and their technical solutions that require basic scientific research commonly go unfunded, as needs whose higher priority is based on the urgency of their latest deployment dates consume the available budget.

To achieve a portfolio of projects that is better balanced between near-term priorities driven by specific programmatic risks (for example, site closure milestones) and long-term, high-consequence needs that depend on extensive research and development, OST has established the EMSP to develop the scientific basis for solutions to such long-term site needs. It is important to achieve a balance between rapid deployment of technology and research to support new technology to ensure that technical solutions will continue to fill the pipeline to meet site needs. Periodically the EMSP will direct a call for proposals to address the scientific needs of each focus area in turn.

Needs Identification in the NMFA

Needs are identified and validated on an annual basis by individual sites in a series of workshops conducted across the DOE complex. The process is intended to capture the site requirements both of scope and schedule, so that Focus Areas can identify technology that can be made available to sites in time to complete site cleanup. Especially important in this process is the identification of critical path milestones and deliverables for significant projects (identified as Project Baseline Summaries – PBSs). Needs are assigned to the different product lines of a Focus Area.

Table II. OST gate model for technology development and deployment (major gates are titled)

Stage	Activities
Gate 0: Idea for Research	
Basic Research	Knowledge building, theory development, laboratory experimentation, proof of principle
Gate 1:	
Applied Research	Laboratory experimentation, definition of material requirements and design concepts, definition of cost requirements
Gate 2: Research to Development	
Exploratory Development	Technical feasibility demonstration, laboratory-scale prototyping, estimation of costs
Gate 3:	
Advanced Development	Proof of design, full-scale laboratory testing, preliminary field design, development of technical specifications
Gate 4	
Engineering Development	Full-scale design, prototype and pilot-scale testing, reliability testing
Gate 5: Development to Demonstration	
Demonstration	Short-term operation with actual material, proof of economic viability
Gate 6: Demonstration to Deployment	
Deployment	Full-scale routine operation with actual material, continued demonstration of economic viability, evaluation of additional applications

The NMFA has a number of science needs in its portfolio. These needs may be found on the Site Technology Coordination Group (STCG) home page for each individual site. For example, the INEEL's needs may be found at http://www.inel.gov/st-needs/. To date the NMFA has been able to fund directly only a few projects to address scientific needs. It is anticipated the EMSP will direct a call towards these needs in FY03. The NMFA product line managers, with input from its end-users, will assist in preparation of this call and prioritization of the science needs.

The Nuclear Material Focus Area consists at present of four product lines. Two were originally created to address the disposition of excess nuclear materials, primarily plutonium, and are divided on functional lines. These product lines are:

- Processing and Stabilization
- Packaging, Transportation & Storage

The functional relationship of these product lines is shown in Figure 1. Since their creation, two new product lines have been added that are tied to particular programs to dispose additional categories of nuclear material:

- Spent Fuel
- Depleted Uranium

Each product line has some science needs related to its work.

SCIENCE NEEDS FOR THE NMFA

Table III lists the science needs of the NMFA, and also identifies the site defining the need and the NMFA product line responsible for preparing a technical response to the need. Not all needs have been sufficiently well defined that the scientific component can be clearly identified. NMFA experience has shown that a variety of needs require some period of interactive redefinition to ensure that a clear set of requirements can be laid out, and a research, development, and deployment path established to meet the need. The technical response process commonly addresses this issue.

The science needs identified by end users of the NMFA fall into three technical areas, with additional generic needs in several other crosscutting areas. The first of these encompasses needs for better understanding of chemical processes applied to current or expected material streams being processed for stabilization and storage at various sites. The second area constitutes a range of needs associated with understanding gas generation likely to occur within storage containers for various nuclear materials, including spent nuclear fuel, as well as metal, oxide and other compound forms of plutonium, uranium and other actinides. The final technical category consists of needs in a variety of material science arenas, ranging from accident testing design and implementation and welding technology to short- and intermediate-term corrosion to long-term degradation processes. The remainder of this section amplifies the table with a brief discussion of areas of science need within the categories discussed above.

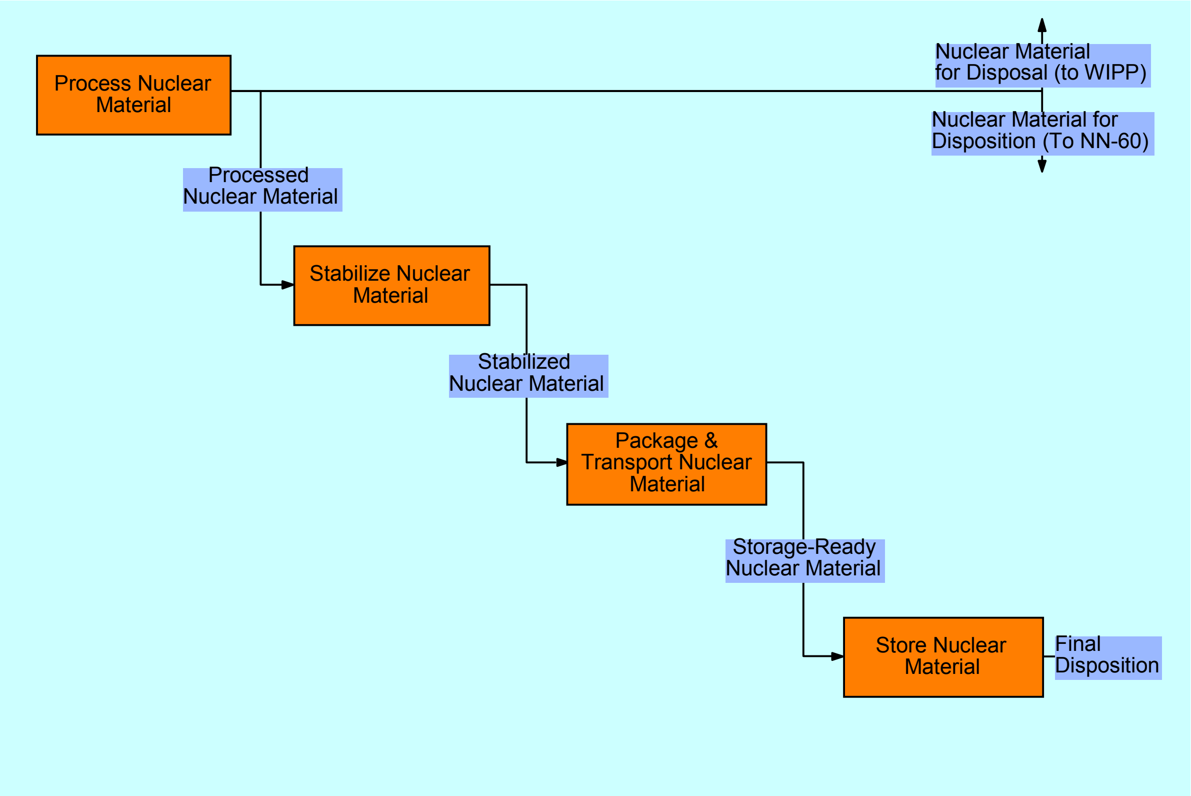

Fig. 1. Product Line Functional Relationship

The newly identified Depleted Uranium (DU) product line has identified a general category of needs in the area of reuse of depleted uranium that will likely require some basic science research to bring technology to bear on reducing the need to dispose of the DU as waste. Few specific needs have been entered into the needs management system at this point. In addition, there are a few needs that simply describe the requirement for a technical basis for stabilization and storage of materials such as spent fuel and some actinides. To some extent, these needs are identified as aspects of more generic needs that are partially technology needs, and partially needs for basic science.

Table III. Science Needs of the Nuclear Material Focus Area

Need Code	**Need Name**	*Site*	**NMFA Product Line**
Chemical Processing Science			
RL-DD034-S	Thermodynamic Data for Plutonium Nitrate	Hanford	Processing
RL-DD036-S	Modeling Thermodynamic Properties	Hanford	Processing
SR02-5070S	Prevention of Precipitation of Unwanted Solids During Nuclear Material Processing	Savannah River	Processing
AL-02-01-14-NM	Pu239 Metals and Compounds Flow sheet Development	Los Alamos	Processing
AL-02-01-15-NM	Pu239 Combustibles Flow sheet Diagram	Los Alamos	Processing
SR02-5065S	Interaction of Actinide Solutions with Concrete	Savannah River	Processing
SR02-6024S	Fundamentals of Off-Gas Technology	Savannah River	Spent Fuel
Gas Generation Science			
SR02-6029S	Water Radiolysis and Transportation of Spent Nuclear Fuels (SNF)	Savannah River	Spent Fuel
ID-S.1.20	Bound Water Radiolysis Investigation	Idaho	Stabilization
AL-02-01-09-NM-S	Radiolytic Stability of Chemisorbed Moisture on Nuclear Materials	Los Alamos	Stabilization
SR02-5064S	Understanding the Effect of Surface Chemistry on the Radiolysis of Moisture Adsorbed in Plutonium Dioxide Surfaces	Savannah River	Stabilization
AL-02-01-10-NM-S	Role of Recombination of O_2 and H_2 in Pressurization of Nuclear Material Containers	Los Alamos	Stabilization
RL-DD032-S	Measurement of Moisture Content in Plutonium Oxides and other Materials for the Plutonium Finishing Plant (PFP)	Hanford	Stabilization
AL-02-01-07-NM-S	Non-destructive Assay (NDA) of Moisture Content of Nuclear Material	Los Alamos	Stabilization
Material Science			
AL-02-01-08-NM-S	Prediction of High Temperature Corrosion in Limited Moisture Environment	Los Alamos	Packaging, Storage
SR02-6025S	Science - Corrosion Performance Storage for Uranium Tri-Oxide at Savannah River Site (SRS)	Savannah River	Packaging, Storage, DU
SR02-6019S	Science - Definition of the Basin Corrosion Envelope for Savannah River Site (SRS) Aluminum (Al)-clad Spent Nuclear Fuels (SNF)	Savannah River	Spent Fuel
SR02-6030S	Science - Corrosion Performance of Aluminum(Al)/ Zirconium(Zr)/ Stainless Steel (SS) Clad Fuels at Savannah River Site (SRS)	Savannah River	Spent Fuel
RL-SNF13-S	Oxidation and Hydride Formation in U Metal SNF	Hanford	Spent Fuel
SR02-6027S	Science - On-Line Corrosion Monitoring for Savannah River Site (SRS) Spent Nuclear Fuels (SNF) Basins	Savannah River	Spent Fuel
ID-S.1.06	Detect and Mitigate Microbiologically Induced Corrosion in Spent Nuclear Fuel Dry Storage Containers	Idaho	Spent Fuel
ID-S.1.21	High level waste glass and spent nuclear fuel interactions	Idaho	Spent Fuel
SR01-6011S	Interactions Between Spent Nuclear Fuel, Storage Containers, and High Level Waste in Repository Co-Disposal Packages	Savannah River	Spent Fuel
ID-S.1.22	Long term degradation of aluminum based fuel	Idaho	Spent Fuel
ID-S.1.23	Long term degradation of thorium/uranium carbide fuel	Idaho	Spent Fuel
ID-S.1.24	Degradation of neutron absorbers in waste packages	Idaho	Spent Fuel

Need Code	**Need Name**	*Site*	**NMFA Product Line**
SR02-6022S	Science - Development of Insoluble Neutron Poison Materials for Spent Nuclear Fuels (SNF)	Savannah River	Spent Fuel
SR01-6015S	Technology Development for Closure Welds of Spent Nuclear Fuel	Savannah River	Spent Fuel
SR02-5063S	Packaging and Transportation Test Program of Impact/Crush/Thermally Resistive Materials	Savannah River	Spent Fuel
Standard Development (Gas Generation and Material Science)			
SR00-6003S	Technical Basis for Dry Storage of Spent Nuclear Fuel	Savannah River	Spent Fuel
SR02-6021S	Development of Technical Basis for Standards for Interim Wet and Dry Storage of Spent Nuclear Fuels (SNF)	Savannah River	Spent Fuel
AL-01-01-07-NM	Develop Tech Basis for Np Stabilization/Packaging/Storage Standard	Los Alamos	Stabilization
AL-01-01-08-NM	Develop Tech Basis for Am/Cm Stabilization/Packaging/Storage Standard	Los Alamos	Stabilization
Reuse of Depleted Uranium			
AL-01-01-18-NM	Identify New Uses for Depleted Uranium	Los Alamos	Depleted U
ORNM-23	Beneficial Reuse of Depleted Uranium	Oak Ridge	Depleted U
SR00-5012	Depleted Uranium Trioxide Utilization	Savannah River	Depleted U

Science Needs in Chemical Processing

Science needs in the chemical processing area fall under the scope of the Processing product line, but also include needs from the Spent Fuel product line. They constitute needs addressing improvements to existing processes, as well as more general needs for the development of technical flow sheets for processes addressing materials that have not yet been dealt with.

Thermodynamic properties of nuclear materials and solutions: Needs are defined at Hanford, Los Alamos and Savannah River for fundamental thermodynamic data and improved models to support processing of nuclear materials (especially Pu) prior to final stabilization. For a number of species that facilities such as the Savannah River Site canyons expect to encounter in the processing of nuclear material solutions, enthalpies and Gibbs free energies of formation are not well known. In the absence of data, chemical models may be used, but these too need improvement to cover the range of material the DOE expects to process over the next few years. Improved models for activity coefficients in complex salt solutions are also needed to avoid problems arising from precipitation of solids during processing.

Flow sheets for processing of nuclear material streams: Development of potential flow sheets for improved processing of nuclear materials requires investigation of data and possible technical options for dissolution of particularly insoluble inorganic compounds containing plutonium, and for processing of reactive materials without generation of hydrogen gas. These needs are defined at Savannah River and Los Alamos.

Technical issues for existing or planned processes: Savannah River has defined a need to understand the reaction (including actinide speciation and surface interactions) of process solutions containing actinides with the concrete in canyon facilities to facilitate cleanup required due to criticality concerns.

In addition, Savannah River has identified a need for improved understanding of the potential off-gassing during melt-dilute treatment of highly enriched uranium/aluminum metal spent fuels. A fundamental model that predicts trapping and absorption from the off-gas streams would provide a technical basis to assure safe and efficient system operation of the melt-dilute process and have general applicability to off-gas streams

The processing product line also identified needs for fundamental science in:

- actinide solution chemistry,
- actinide purification chemistry,
- material characterization
- morphology of Pu metal and oxide

Science Needs in Gas Generation

Science needs in gas generation come from the Stabilization product line, the Packaging and Transportation product line and the Spent Fuel product line. They include needs for fundamental understanding of the properties of hydrogen as hydroxide and water on the surface of fuels and stabilized nuclear materials such as plutonium oxide and metal.

Radiolytic properties of hydrogen as hydroxide and water on stabilized nuclear material: Needs have been identified by Savannah River, Idaho and Los Alamos for improved understanding of the process of radiolytic hydrogen generation from water and hydroxide on spent fuel and stabilized metals and oxides of various actinides within sealed containers.

Surface chemistry of stabilized nuclear material: Improved understanding of the surface chemistry of plutonium and other actinide metals and oxides has been identified by Los Alamos as important to assuring the stability of nuclear material after calcination. Of particular concern is the potential effect of formation of superstoichiometric plutonium oxide as a sink for radiolytically generated oxygen.

Recombination properties of hydrogen and oxygen in radioactive environments: Los Alamos has identified a need for improved understanding of the recombination properties of radiolytically generated O_2 and H_2 to better constrain the allowable water content of stabilized nuclear material. If lower limits for recombination can be well established, sites will have greater flexibility in processing nuclear material.

Development of techniques for measurement of low moisture content in nuclear material: Los Alamos has identified a need for methods to measure the moisture content of stabilized nuclear material in sealed containers, including pure and impure plutonium oxides and other materials, such as uranium oxides and mixed oxides. The need to measure after sealing indicates that a nondestructive assay is required.

Additional potential science needs identified by the product lines include:

- hydrogen gas sensors,
- getter materials for metal and oxide storage packages,
- shipping needs related to neptunium and other actinides
- radiolysis by actinides other than Pu
- improved modeling capabilities for nuclear materials/container interactions, and
- Spent fuel modeling capabilities

Science Needs in Material Science

Science needs in the Material Science area come from the Long Term Storage product line, the Depleted Uranium product line, and the Spent Fuel product line. They include a variety of needs for understanding of corrosion and long-term degradation of both nuclear material and container material used to store and dispose of that material. For spent fuel, these include potential neutron poisons for criticality control. Additional needs exist for welding technology for containers, and for comprehensive testing of spent fuel packages for transportation. A number of the needs identified require development of modeling capability for nuclear material and container material. Finally, the NMFA has identified a number of material characterization needs that fall into this category.

Corrosion of materials for processing and storage of nuclear material: Los Alamos has identified a need for better understanding of the corrosion processes likely to affect stabilized nuclear material (primarily Pu) in sealed containers over periods of ten to fifty years. In particular, improved understanding is required of the competition between metal of the container and the nuclear material for moisture and its breakdown products in the container environment.

Savannah River has identified a need for scientific data to define storage requirements for uranium trioxide powder. Degradation of some containers for this material indicates a need to quantify relevant corrosion parameters for the container, the polymer liner, and for the oxide itself, by means of laboratory and field measurements.

Corrosion processes for nuclear material: Savannah River has identified a need for measurements and calculations to support redefinition of the operating envelope for wet storage basins for Al-, Zr-, and Stainless Steel-clad fuels. The current operating envelope for basin chemistry is based on bounding calculations, and is very conservative. Laboratory testing and field measurements are required to define a broader envelope, and to define a surveillance and inspection program for the fuel basins. Development of predictive models for extended storage of these fuels is a primary outcome of meeting these needs.

Savannah River has also identified a need for better scientific understanding of the oxidation and hydride formation in uranium metal spent nuclear fuel. At the present time, canisters containing metal fuel are not *a priori* acceptable for storage at the national SNF repository. The metal reactivity, the potential resulting generation of hydrogen, and the creation thereby of fine particles may cause these fuels to not meet the waste acceptance requirements as currently stated in draft form. Therefore consequence analyses are under way at the national level to better define the energetic reactions and particle releases from breached canisters containing metal fuel. The need is for primary data to support estimation of the long-term risk of such a failure. Increased understanding may also improve the confidence in decisions made in future years on the necessity to vent or repackage the fuel

Measurement of corrosion in processing and storage of nuclear material: Savannah River has identified a need to develop on-line, remotely monitored tools to measure corrosion of Al-, Zr-, and stainless steel-clad fuel. Idaho has identified a need for tools to characterize the features of the microbiota living on spent fuel to determine the mechanisms of microbial corrosion on spent fuel storage materials. The need extends to measures of total biomass, spatial distribution, physiologic and metabolic capabilities, and electrochemical and oxygen potential of biofilms on surfaces. Effects of metallurgical inhomogeneity on potential corrosion processes are also important. These need to be understood as they evolve through time, and with the various process stages for the spent fuel.

Long-term degradation of spent nuclear fuel and interaction with near-field materials: High-level waste glass will be packaged in the same container as spent nuclear fuel for disposal at the high level waste repository. Once the container is breached, groundwater can enter and degradation of the contents will begin. Although experiments are in progress to evaluate the reactions between groundwater and HLW and SNF individually, no tests are being done with the combination. Idaho and Savannah River identified a need to evaluate interactions under repository conditions with at least two, preferably three, fuel types (uranium metal, aluminum based, and mixed oxide fuels are recommended in order of preference). Identification and characterization of corrosion products generated by the interaction of co-disposed DOE spent nuclear fuel (SNF), defense high level waste (DHLW) glass, and waste form containers in repository ground water environments is needed to aid the disposal of the DOE SNF in a mined geologic repository. The complex series of interactions that are possible in the operating environment of the repository are of greatest significance with respect to how they impact the generation and immobilization of radionuclide-associated colloids/products and accelerated container corrosion. Modeling capabilities to support repository performance assessment are an integral part of this need. Idaho has also identified a need to study the long-term corrosion processes for aluminum based metal fuel and thorium/uranium carbide fuels.

Development and measurement of properties for neutron absorbers: Idaho and Savannah River have identified a need to develop and characterize the long-term degradation properties of neutron absorbers that are planned to be included in high level waste/spent nuclear fuel waste packages for criticality control of highly enriched spent fuel. The goal is to have the absorber material maintain close proximity to the fissile material regardless of reconfiguration over time. Knowledge of the characteristics of the absorber material over time needs enhancement. Specifically, experiments are needed to evaluate the degradation characteristics of the absorber material as well as the interactions between the absorber and other waste package materials.

Weld technology for containers: Idaho has identified the need to develop enhanced welding processes for sealing of spent fuel containers. Development of narrow-gap groove welding techniques to minimize the overall heat input required for weld closure and development of weld repair techniques that minimize heat input by early detection of weld defects through the application of real-time non-destructive evaluation processes is needed. This need is likely to contain a substantial component of technology development, but may require research on specific characteristics or methods of characterization.

Testing of packaging and transportation material: A program is needed to comprehensively test and document existing and new materials that could be used in the design of new packages for spent fuel. Packaging designs that undergo certification use a variety of insulation and impact absorbent materials to ensure performance against regulatory drop and fire tests. Materials used for this purpose typically serve dual purposes, *i.e*., the material serves as both an insulator and an impact absorber. In some instances, these materials will also have to resist crushing based on additional regulatory test requirements. Currently, there is no database of applicable properties for these materials. An approved compendium of these properties would significantly improve regulatory acceptance of materials that are used for package design. Documentation would be in the form of a recognized Nuclear Regulatory Commission (NRC) NUREG.

Additional potential science needs identified by the product lines include:

- improved modeling capabilities for nuclear material/container interactions
- security/non-proliferation determination of nuclear material
- remote, presumably nondestructive characterization (for additional constituents besides moisture) of spent fuel and other nuclear material
- chemical and physical sensors for spent fuel and other nuclear material
- Nondestructive assay (NDA) systems
- sensors/detectors

Science Needs for the Technical Basis of Storage Standards

Sites have identified a need for technical basis data to support the development of standards for stabilization, packaging, transportation and long-term storage of several nuclear materials, including spent fuel, neptunium, and americium.

Dry storage of spent nuclear fuel: Currently, DOE stores spent nuclear fuels primarily in wet basins at numerous sites throughout the complex. Idaho, Savannah River, and Hanford have documented degradation/corrosion of the spent fuel assemblies in wet storage resulting mainly from poor water chemistry control. Degradation of the SNF posses several problems that ultimately result in increased cost for continued storage and management. The development of consensus standards for wet and dry storage will provide a uniform basis for operation and ready acceptance by all stakeholders.

Dry storage of stabilized special nuclear material: Los Alamos, as the lead laboratory for the DNFSB 94-1 Research and Development program, has identified a need for a consensus standard to guide the stabilization, packaging and storage of Np materials at LANL and other DOE complex sites. A path forward must be defined to establish the requirements of the standard and the underlying technical basis must be developed. This need is expected to require some basic science effort.

Los Alamos has also identified a need for a consensus standard to guide the stabilization, packaging and storage of Am/Cm materials at LANL and other DOE complex sites. A path forward must be defined to establish the requirements of the standard and the underlying technical basis must be developed. This need is expected to require some basic science effort.

Science Needs for Depleted Uranium Reuse

The Depleted Uranium product line addresses the technology needs related to the stabilization, processing, conversion, and potential beneficial use or disposition of depleted uranium (DU), stored primarily as UF_6. The Depleted Uranium product line has only recently been established within the NMFA (in collaboration with the Oak Ridge Office of the Office of Site Closure [EM-32]). The scope of this product line is currently being defined. Savannah River and Oak Ridge have identified needs in the area of enabling alternative disposition paths (besides disposal) for DU. However disposition of depleted UF_6 and other forms of DU will likely require the development and deployment of new technologies to ensure safe, timely and cost-effective disposition. Currently identified new technical solutions with potential research requirements prior to deployment include:

- Spent nuclear fuel waste package applications of ceramic metal (cermet) technology
- Use of depleted uranium as semi-conductors
- Use of depleted uranium as catalyst for chemical processing

Crosscutting Science Needs

Crosscutting programs within EM include Robotics, Efficient Separation and Processing (ESP), and Characterization, Monitoring, and Sensor Technologies (CMST). These crosscutting programs have offered a number of basic science research areas to be considered for support of the NMFA's task to dispose nuclear materials. These programs offer a broader (complex-wide) perspective of needs than do site-specific needs. Several general needs have been suggested. In previous years, the NMFA has funded a limited amount of research under the auspices of the Robotics and CMST programs.

The Robotics program has identified several areas where basic science research could provide valuable new technologies. These include

- automated guarantee of system integrity after delivery
- standardized vision system
- visual servo control
- work cell I/O simulator
- improved force control
- tetherless support

The CMST program has identified two areas where basic science research could support NMFA needs for measurement within a sealed storage container.

- Gas constituent identification
- Pressure measurement

The ESP program has identified two potential areas that could support the NMFA.

- Optimized precipitation in solutions stabilization and processing
- Actinide flow sheet development for new processes within existing facilities and equipment

CONCLUSION

Within each of its product lines, the NMFA has validated a number of needs, identified across the DOE complex, that require an understanding of new basic science. This research is anticipated to lead to new technologies to solve these difficult problems. These advances are expected to reduce costs, schedules, and risks associated with the disposition of materials related to the NMFA. Prioritization of these needs and identification of crosscutting needs is currently underway as part of the NMFA planning process. It is anticipated that a number of these areas of basic science will be addressed in an upcoming EMSP call directed toward the NMFA's needs.

The ability of technology to save money for a given task affects DOE's overall baseline cost, but also accelerates work because projects are consistently constrained by budget. Likewise, technology that accelerates throughput may not immediately reduce cost, but can do so by removing facilities from the DOE mortgage. Finally, technology that enables hitherto unsolvable problems to be addressed can reduce cost and shorten facility schedules.

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