U.S. DEPARTMENT OF ENERGY

PLUTONIUM FOCUS AREA

DOE/ID-10631
Revision 0

Plutonium Stabilization and Disposition Focus Area

FY 1999 & FY 2000

Multi-year Program Plan

March 1998

DISCLAIMER

DOE/ID-10631
Revision 0

Plutonium Stabilization and Disposition Focus Area

FY 1999 & FY 2000

Multi-Year Program Plan

Published March 1998

Prepared for the
U.S. Department of Energy
Idaho Operations Office

SUMMARY

Consistent with the Environmental Management's (EM's) plan titled, "Accelerating Cleanup: Paths to Closure", and ongoing efforts within the Executive Branch and Congress, this Multi-Year Program Plan (MYPP) for the Plutonium Focus Area was written to ensure that technical gap projects are effectively managed and measured. The Plutonium Focus Area (PFA) defines and manages technology development programs that contribute to the effective stabilization of nuclear materials and their subsequent safe storage and final disposition. The PFA is chartered under the DOE Idaho Operations Office with support from Lockheed Martin Idaho Technologies Company (LMITCO) and Argonne National Laboratory (ANL).

The scope of PFA activities includes the complete spectrum of plutonium materials, special isotopes, and other fissile materials. The PFA enables solutions to site-specific and complex-wide technology issues associated with plutonium remediation, stabilization, and preparation for disposition to:

- Expedite complex-wide progress
- Standardize resolutions, practices, and equipment systems
- Promote integration/interfacing
- Produce more cost-effective programmatic results.

Currently, the technological development projects are derived from the *Plutonium Focus Area Research and Development Plan*, the latest revision is DOE/ID-10561 Revision 2, November 1997. This R&D Plan defines the current gaps in technology that could pose significant risk to nuclear materials disposition. PFA recommends and conducts projects that are intended to enhance and expand on existing scientific data for handling, processing, storing, and safely dispositioning nuclear materials by resolving gaps in existing technology.

In the future, the Office of Science and Technology (OST) will play a critical role in supporting the Office of Environmental Management's objectives relative to nuclear materials stabilization and disposition. We anticipated future OST planning in this area to evolve from the current R&D Plan. Continuity in technology gap definition, and in PFA management of ongoing development programs is expected. PFA will continue to provide management attention to the ultimate safe disposition of nuclear materials.

The information presented here is in a format that focuses on the problem, benefit, drivers, and impact of investing in the work. The customer needs, strategies, and objectives are described with site wide buy in, strategic need ties, and cross-cutting initiatives. The FY 1999 program continues to support the Defense Nuclear Facilities Safety Board's (DNFSB) 94-1 technology gaps. The FY 2000 program planning, however, is in its infancy and consists of new technologies that respond to the broader plutonium residue questions in the DOE

complex. This planning will mature in FY 1999 with site buy-ins on specific waste stream technology gaps. We anticipate the planning evolving from both the new and old programs will include an even larger priority listing of development projects best accomplished through the PFA.

Table 1 provides a picture of what PFA manages in terms of the technology categories where gaps exist, showing those programs and how they cross-cut to sites throughout the DOE complex.

Table 1. PFA technology summary.

Technology Area/ 1999 Projects	Crosscut Impact	Section in Plan	Technology Summary
Phosphate Bonded Ceramics (FY 1999 and FY 2000)	•Robotics •University	Section 3.1.1	Chemically-Bonded Phosphate Ceramics have been shown to be a stable, leach-resistant waste for immobilization of Plutonium ash and ash heel at the Rocky Flats Environmental Technology Site (RFETS). RFETS has shown a $10M savings and a 9 month schedule improvement using ceramification over their baseline using vitrification.
Encapsulation of HEPA Filter Medium (FY 1999 and FY 2000)	•CMST	Section 3.1.2	After use, fiberglass filters contain transuranic, other radioactive elements, and Resource Conservation and Recovery Act (RCRA) toxic metals. Laboratory tests show fiberglass filter media melts at temperatures below 845°C and can be vitrified in a low melting glass flux. Heavy metals contained on the filter media were retained in the glass disk. This process has many advantages over currently planned treatments including large volume reduction and batch processing for 55 gallon drum disposal using minimal equipment.
Miscellaneous Residue Stabilization Needs Assessment (FY 1999)		Section 3.1.3	Inventories of plutonium residues not included in the major trade studies have no clearly identified path forward. Miscellaneous plutonium residues include insulation; ceramics; scrap metals; fire brick, and LECO crucibles. These inventories consist of about 38MT material containing about 500 kg plutonium. A major Trade Study is needed to define a path forward for this material.
$CaCl_2$ Detection (FY 1999 and FY 2000)		Section 3.1.4	The presence of $CaCl_2$ in pyrochemical salts interferes with the salt distillation process. The Technical Advisory Panel agreed that development of a promising detection technology would reduce schedule uncertainties in the RFETS program.
Plutonium Characterization using Nuclear Magnetic Resonance Spectroscopy (NMR) (FY 1999 and FY 2000)	•Industry •University	Section 3.1.5	Over 10,000 Pu packages requiring repackaging require moisture and corrosive contents determination in which NMR could provide superior NDE results. This would ensure long term storage success.
Salt Distillation (FY 1999 and FY 2000)		Section 3.1.6	Over 18 metric tons of pyrochemical salt residue are in storage within the DOE complex. These salts are considered unacceptable for safe interim storage. Salt distillation was determined to be the preferred technology for salt stabilization in a rebaselining exercise at RFETS. This effort is focused on demonstrating an operable system.
Phosphate Extraction and Stabilization of Radioactive Materials from Miscellaneous Residues	•Efficient Separations •Phosphate Bonded Ceramics	Section 3.1.9	This project would use the properties of phosphates in a process to extract and precipitate out radionuclides from problematic Pu residues. This technology will be included in the path forward Trade Studies for miscellaneous residues (see Section 3.1.3).

Table 1. (continued).

Technology Area/ 1999 Projects	Crosscut Impact	Section in Plan	Technology Summary
^{235}U Stabilization (FY 1999 and FY 2000)	•Robotics •University	Section 3.2.1	Determine the effectiveness of using high-G planetary milling to disposition excess ^{235}U oxide. The ^{235}U oxide would be milled and blended with DU or NU oxide to generate an LEU oxide [e.g., <20% ^{235}U enrichment for recycle purposes (i.e., LWR feedstock) or to <0.9% ^{235}U for disposal]. Once diluted, the radiation fields from the storage containers will be reduced, the uranium will no longer require the high cost of safeguards and security, and the potential for shipping to an "off-spec" aqueous blending site or disposal site will be significantly improved. This is consistent with DOE's policy to identify low-cost alternatives for fissile material disposition.
^{233}U Stabilization (FY 1999 and FY 2000)	•Robotics •University	Section 3.2.2	This project is an extension of the ^{235}U stabilization described in the previous paragraph. If the ^{233}U can be diluted to LEU (<12% ^{233}U) then continued storage costs can be reduced and the transfer to another site is significantly simplified because the safeguards and security issues are eliminated and radiation fields from the storage containers will be reduced. Dilution to the disposal threshold (about 0.67% ^{233}U) would reduce these issues even further and may prove to be more cost effective than aqueous blending, under consideration at SRS.
Porous Crystalline Matrix (FY 1999 and FY 2000) (Russian Collaboration)		Section 3.3.1	The technology provides an alternative to a deployed vitrification process for liquid waste at SRS and is based on using a porous crystalline matrix which absorbs liquids at room temperature. The final waste form is a stable ceramic material, suitable for safe long-term storage and transportation. 15,000 liters of SRS liquid waste contain Am/Cm isotopes that have a commercial value. Recovery of isotopes is possible by dissolving the ceramic in an acid-based solution.
Innovative Conversion of Plutonium Materials to Oxide & Preparing Mixed Oxide Fuel (FY 1999 and FY 2000) (Russian Collaboration)		Section 3.3.2	This task evaluates Russian technology applicable to converting plutonium weapons components to mixed oxide fuel. This evaluation will establish a possible alternative to the ARIES process in this country. An understanding of the Russian technology may be important to future decisions on surplus plutonium disposition.
Integrated Monitoring & Surveillance System (IMSS) (FY 1999 and FY 2000)	•CMST •Robotics	Section 3.4.1	The IMSS provides established resources for process definitive testing of sensor technologies necessary for the monitoring and surveillance of special nuclear material (SNM) in short, intermediate, and long-term storage. The resources include an evaluation facility, necessary infrastructure, a wide range of Pu bearing materials, 3013 packages, NDA systems, prototype storage configurations and an inventory of sensor systems.
Storage Containers Fabricated from Radioactively Contaminated Metal (FY 1999 and FY 2000)	•CMST •University	Section 3.4.2	Fabrication of plutonium storage containers from radioactive scrap metal reduces a significant waste stream while providing containers needed for storage of stabilized Plutonium.

Table 1. (continued).

Technology Area/ 1999 Projects	Crosscut Impact	Section in Plan	Technology Summary
Plutonium Safeguards Data and System Integration (FY 1999 and FY 2000)	•Robotics	Section 3.4.3	New nuclear material vaults to be operated [e.g. Actinide Packaging and Storage Facility (APSF)] will require significant new data integration and analysis capabilities in order to meet DOE and International Atomic Energy Agency (IAEA) reporting requirements. The use of advanced measurement, monitoring, and robotics technologies in the design and operation of this vault is the focus of this project.
Plutonium Metal Fire Prediction and Prevention (FY 1999 and FY 2000)	•University	Section 3.4.4	A computer model for predicting the ignition of unalloyed uranium, including the effect of uranium hydride as a pyrophoric initiator, has previously been developed and validated. This effort will build upon the work to extend the previous model, making it capable of evaluating the ignition potential of Pu and Pu alloys, including effects from the plutonium hydride and sesquioxide compounds that may serve as pyrophoric initiators. This effort is necessary to avoid ignition potential in handling Pu for final disposition and in designing safe interim and repository storage facilities.
Intelligent Monitoring System for Safeguards Applications (FY 2000)	•University	Section 3.4.5	Intelligent Systems for Safeguards Data Analysis are knowledge-based computational methods used to analyze real-time and historical data from sensor and measurement devices used for the monitoring and surveillance of SNM in storage. The primary emphasis of the project is to demonstrate and deploy an intelligent monitoring capability that provides early indications of sensor degradation or failure, material stability problems, and material tampering or diversion. This project will reduce life cycle costs and increase safety and maintainability at SNM storage sites as well as reduce site closure costs at RFETS.
Equipment Deployment & Personnel Dose Minimization for Plutonium Handling Systems (FY 1999 and FY 2000)	•University	Section 3.4.6	This project provides a decision-making resource for operational analysis of the Plutonium Stabilization and Packaging System to be installed at Building 707 at RFETS. A model will be used to estimate operational measures for operational analysis, strategic planning, and personnel dose minimization

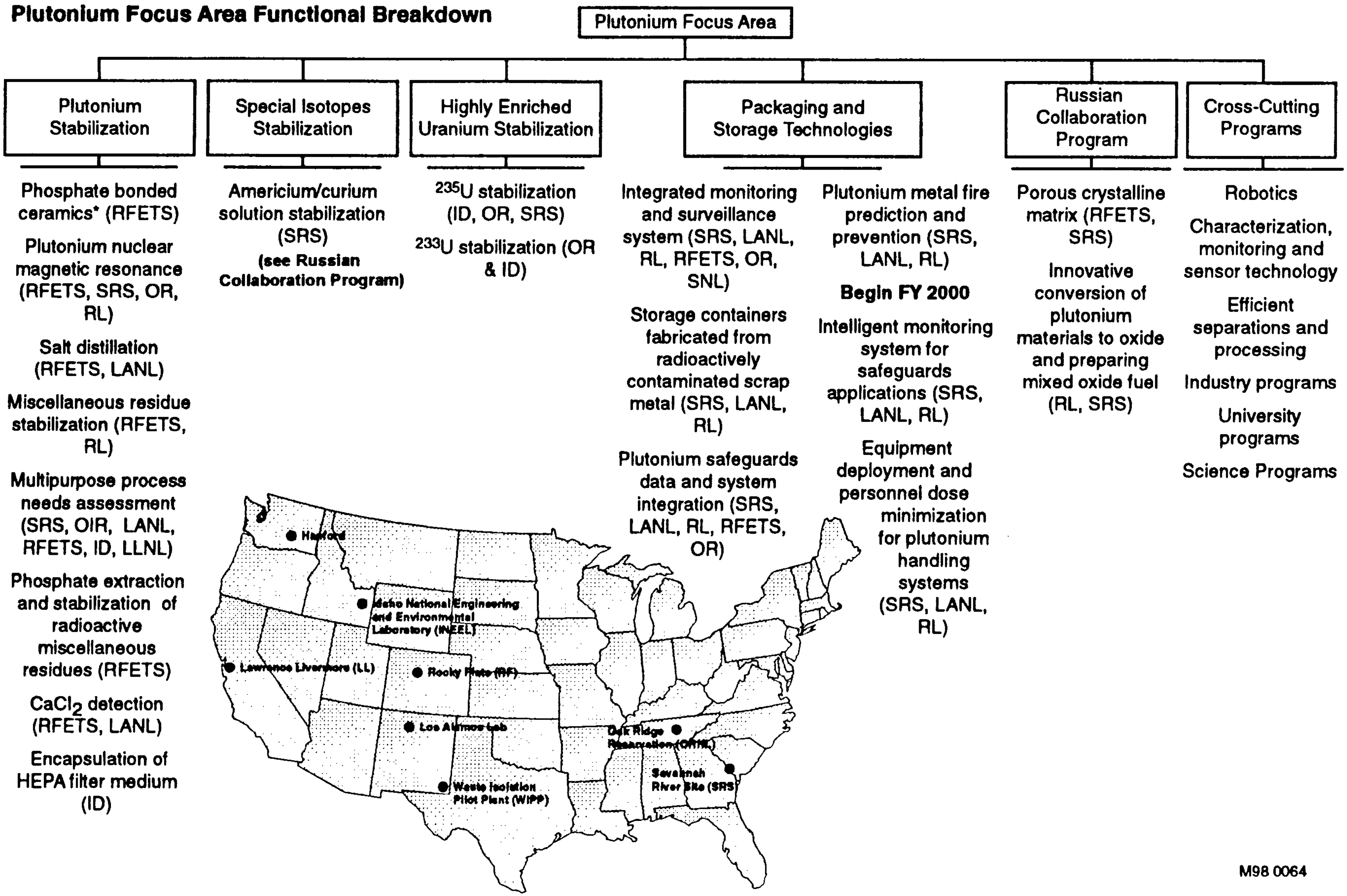

Figure 1. PFA technology areas and their cross cut throughout the complex.

CONTENTS

FIGURES

TABLES

ACRONYMS

ANL	Argonne National Laboratory
APSF	Actinide Packaging and Storage Facility
BNFL	British Nuclear Fuels Limited
D&D	decontamination and decommissioning
DNFSB	Defense Nuclear Facilities Safety Board
DOE	Department of Energy
DOE-EM	Department of Energy Office of Environmental Management
DOE-MD	Department of Energy Office of Materials Dispositions
DOE-NN	Department of Energy Office of Nonproliferation and National Security
DOE-RL	Department of Energy Richland Operations Office
DOE-RW	Department of Energy Office of Civilian Radioactive Waste Management
DOR	direct oxide reduction
DOT	Department of Transportation
EIS	environmental impact statement
ER	electrorefining
FMF	Fuel Manufacturing Facility
FY	fiscal year
GMODS	Glass Material Oxidation and Dissolution System
HEPA	high-efficiency particulate air
HEU	highly enriched uranium
HLW	high-level waste
IAEA	International Atomic Energy Agency
IMSS	Integrated Monitoring and Surveillance System
INEEL	Idaho National Engineering and Environmental Laboratory
IP	Implementation Plan

ISSC	Interim Safe Storage Criteria
ISSDA	Intelligent Systems for Safeguards Data Analysis
LANL	Los Alamos National Laboratory
LLNL	Lawrence Livermore National Laboratory
LLW	low-level waste
LMITCO	Lockheed Martin Idaho Technologies Company
LOI	loss on ignition
LWBR	Light Water Breeder Reactor
MPPF	Multi-Purpose Processing Facility (SRS)
MSE	molten salt extraction
MSRE	Molten Salt Reactor Experiment
NDA	nondestructive assay
NEPA	National Environmental Policy Act of 1969
NMR	Nuclear Magnetic Resonance
NMSTG	Nuclear Material Stabilization Task Group
NRC	Nuclear Regulatory Commission
ORNL	Oak Ridge National Laboratory
PFA	Plutonium Stabilization and Disposition Focus Area
PuSPS	Plutonium Stabilization and Packaging System
R&D	Research and Development
RCRA	Resource Conservation and Recovery Act
RFETS	Rocky Flats Environmental Technology Site
RSM	Radioactively-contaminated Scrap Metal
SNF	spent nuclear fuel
SNM	special nuclear material
SRS	Savannah River Site
STCG	Site Technology Coordinating Groups

STEA	Safeguard Technology Evaluation Area
STL	Safeguard Termination Limit
TAP	Technical Advisory Panel
TRU	transuranic waste
WAC	Waste Acceptance Criteria
WIPP	Waste Isolation Pilot Plant

Plutonium Stabilization and Disposition Focus Area

1. INTRODUCTION

1.1 PFA Description

On May 26, 1994, the Defense Nuclear Facilities Safety Board (DNFSB) issued Recommendation 94-1, expressing the Board's concern about the safety of DOE nuclear materials. Specifically, the halt in weapons production froze the manufacturing pipeline, leaving it in a state that could not be permitted to exist unremediated. The DNFSB expressed concern about certain liquids and solids containing fissile materials and other radioactive substances that were potentially unstable and posed a high-risk. The DNFSB recommended that DOE stabilize and repackage high-risk material within 2 to 3 years, and the remaining materials within 8 years. The DOE accepted DNFSB Recommendation 94-1 August 3, 1994, and established management oversight organizations to facilitate the stabilization and disposition of materials, plutonium being one of them. They also committed to a research and development (R&D) program to support the technology needs to convert and stabilize its nuclear materials for safe storage. The Office of Environmental Management (EM) is key in identifying new or alternative technologies that can overcome the obstacles to reach a timely and efficient cleanup of the DOE complex.

The Office of Science and Technology (OST) provides the interface to improve existing technologies, find new technologies, and overseeing research activities with fewer cleanup risks and costs while providing new or streamlined solutions for problems. The current draft Accelerating Cleanup, Defining Paths to Closure, identifies over 500 technology needs, of which 160 can be filled with existing demonstrated technologies.

The Plutonium Stabilization and Disposition Focus Area (PFA) is the organization that provides the research and infrastructure to integrate solutions to plutonium stabilization and disposition throughout the DOE complex. The PFA is responsive to user needs and fully integrates knowledge from throughout the complex.

1.2 PFA Mission Statement

The PFA Mission as it relates to the Accelerating Cleanup: Paths to Closure Plan is to:

- Work closely with EM-50 at DOE Headquarters and each site, EM-60 and others who are responsible for nuclear materials stabilization, and the Technical Advisory Panel to ensure that the technology development required to drive the 94-1 stabilization process to closure is completed timely and effectively

- Develop integrated solutions to obtain multi-site benefits in nuclear materials stabilization

- Enhance and apply existing technologies to nuclear materials stabilization

- Work with the sites and stakeholders to ensure that the technologies developed are effectively implemented.

The PFA will actively identify integration opportunities with commercial industries and academic organizations. The scope of PFA activities includes the full spectrum of plutonium materials, special isotopes, and other fissile materials. The PFA is oriented on technologies that lead to effective stabilization of nuclear materials and their subsequent safe storage and final disposition. The focus area will enhance and expand on the scientific data already developed on general chemical and physical processing and the storage behavior of nuclear materials to ensure safe and cost efficient handling, and ultimate safe disposition.

1.3 PFA Strategy

1.3.1 PBF Programmatic Strategy

The PFA Programmatic Strategy as it relates to the Accelerating Cleanup: Paths to Closure Plan is to:

- Identify and develop technologies to fill gaps to stabilize, store, and disposition fissile material residues
- Identify faster, smarter, and cheaper ways to accelerate cleanup, processing, storing, and final disposition of DOE complex Pu residues
- Develop programs and plans to integrate solutions for site-wide problems
- Work with DOE sites and stakeholders to gain consensus on the needs of technology development to fully implement solutions for nuclear material stabilization problems
- Establish and expedite the agreed upon technology development projects
- Implement new technologies.

1.3.2 PFA Technical Strategy

The PFA Technical Strategy as it relates to the Accelerating Cleanup: Paths to Closure Plan is to:

- Provide the Technical Advisory Panel (TAP) with the technical personnel and resources to develop plans for technical needs in the nuclear materials stabilization area
- Keep abreast of the technology development that is being accomplished across the complex, in industry, and academia
- Provide a Systems Engineering approach for alternative solutions and decide the best technical options
- Propose technology development programs to DOE for incorporation into the budget.

1.4 PFA Structure and Organization

1.4.1 Management Structure

Figure 1 shows the PFA organization. The PFA Manager is responsible for all functions of the PFA and is accountable to senior EM-50 management. The PFA Manager or his designee will sign all official correspondence from the PFA. The PFA Manager has the ultimate responsibility for the quality of all PFA activities.

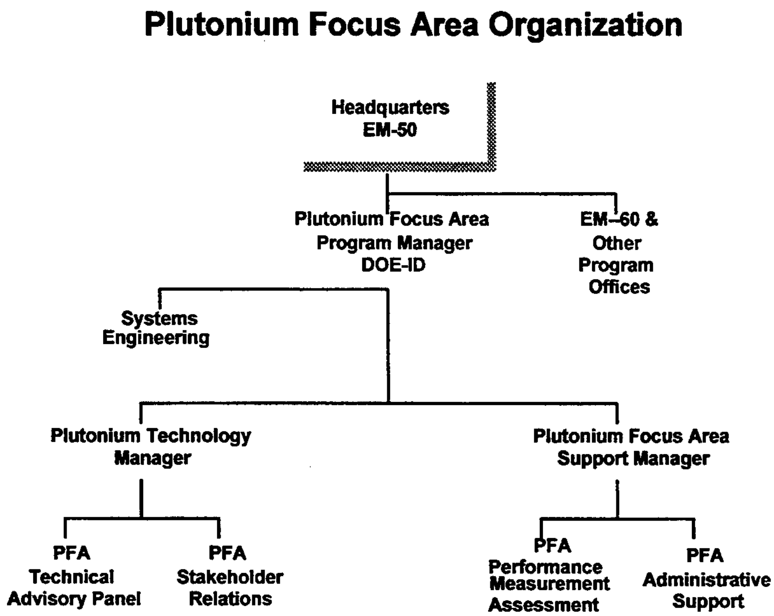

Figure 1. Plutonium Focus Area organization.

The Plutonium Focus Area has two primary divisions, Plutonium Technology and PFA Support. Plutonium Technology composed of the Technology Advisory Panel (TAP) and Stakeholders Relations activities is responsible for PFA technical functions. The PFA Support function is composed of the administrative support, Systems Engineering, and Performance Measurement and Analysis areas.

DOE-ID is responsible for the management and tasking of the PFA and for providing a formal interface with the DOE program and field offices. The manager of each of the two PFA sections will serve as the point of contact, integrate the activities of the groups within each section, and maintain communication between the groups and EM-50 management. The roles and functions of the specific groups are discussed in the overview below. All sections are discussed in more detail later in this section.

- Technical Advisory Panel: The PFA will develop a TAP to identify and address technical and organizational issues surrounding nuclear material stabilization and management. The panel will be composed of select senior technical experts from the DOE complex. Primary TAP functions will oversee, review, and provide technical recommendations. In addition, the TAP will update the Research and Development Plan annually.

- Systems Engineering: The PFA will use a Systems Engineering approach to perform the following activities:
    - Define and flow down requirements and specifications
    - Define functional systems
    - Development, analyze, and implement alternatives
    - Develop and analyze trade studies
    - Evaluate and validate systems performance.

- Systems engineering provides EM with a top down analysis of the complex-wide issues within the PFA charter. By using systems engineering, the PFA ensures that requirements are identified, understood, and managed; analysis identifies gaps in technology research; representation on the TAP by each cognizant DOE facility enables technology and processes to be integrated complex-wide, thereby efficiently allocating scarce resources; duplicated efforts are minimized or prevented; and proof of principal concepts are tested and validated against requirements.

- A PFA lead systems engineer will reside on-Site in DOE Headquarters to provide an accessible and responsive interface for EM-50. The systems engineering approach enables EM-50 and DOE Headquarters to closely and accurately monitor systems efficiency, characterization, quantification, and general assessment of impacting factors. The PFA will provide systems engineering support to EM-50 and other DOE offices who deal with plutonium stabilization and storage issues, depleted uranium handling and storage issues, and other radioisotopes of interest.

- Performance Measurement and Analysis: The primary mission of the Performance Measurement and Analysis group will be to provide the PFA with program support, including schedule, cost, and performance analysis. The Performance Measurement and Analysis group will also maintain the integrated schedule database that tracks commitments and milestones. This PFA database will monitor and evaluate progress to meet external commitments.

- Administrative Support: The Administrative Support group will clerically and administratively support PFA members. Document control, travel coordination, commitment tracking, and other clerical duties activities are within the purview of the Administrative Support Group.

2. PROGRAM DEVELOPMENT PROCESS

2.1 Prioritization

The PFA uses a prioritization process that involves reviewing site needs through established documentation such as the Site Technology Coordinating groups (STCG), the Research and Development Plan, the Accelerating Cleanup, Paths to Closure Plan, (Draft) and other pertinent documentation. The PFA TAP, composed of experienced key site representatives, reviews the project priority list.

2.2 Priority Listing

The table below depicts current prioritized technology gaps identified by the PFA:

Number	Section	Project Title
1	3.1.1	Phosphate Bonded Ceramics
2	3.4.1	Integrated Monitoring and Surveillance System (MSS)
3	3.1.2	Encapsulation of HEPA Filter Medium
4	3.3.1	Porous Crystalline Matrix
5	3.4.2	Storage Containers Fabricated from Radioactively Contaminated Material
6	3.1.3	Miscellaneous Residues Stabilization Needs Assessment
6b	3.1.9	Phosphate Extraction and Stabilization of Radioactive Materials
7	3.1.4	$CaCl_2$ Detection
8	3.2.1	^{235}U Stabilization
9	3.2.2	^{233}U Stabilization
10	3.1.5	Plutonium Characterization using Nuclear Magnetic Resonance Spectroscopy (NMR)
11	3.3.2	Innovative Plasma Conversion of Plutonium Materials to Oxide
12	3.4.3	Plutonium Safeguards Data and System Integration
13	3.1.7	Ceramics for Plutonium Halide Residues
14	3.4.4	Plutonium Metal Fire Prediction and Prevention
15	3.1.8	Stabilization of Zero Power Physics Reactor Plutonium
16	3.4.6	Equipment Deployment and Personnel Dose Minimization for Plutonium Handling System
17	3.4.5	Intelligence Monitoring System for Safeguards Application

3. PLUTONIUM FOCUS AREA TECHNICAL ACTIVITIES

3.1 Plutonium Stabilization

3.1.1 Phosphate Bonded Ceramics (FY 1999 & FY 2000)

3.1.1.1 Project Summary. Chemically-Bonded Phosphate Ceramics (CBPC) have been demonstrated as a highly stable, leach-resistant means for immobilization of Pu-bearing ash and ash heal used to meet DNFSB 94-1 R&D concerns. This project supports the rebaselining of the residue treatment program at the Rocky Flats Environmental Technology Site (RFETS). Specific programmatic needs at RFETS derive from stabilization requirements and plutonium content restrictions, i.e. Safeguard Termination Limits (STLs) for transuranic waste drums destined for disposal at the Waste Isolation Pilot Plant (WIPP).

CBPC will provide the fast-paced waste stabilization enhancement necessary to meet 94-1 milestones. The PFA has recommended a demonstration of nonthermal ceramification of selected key RFETS residues beginning with technology demonstration and specimen testing on waste forms fabricated with RFETS ash residues. Feasibility testing and process adaptation is underway to verify performance and develop specific optimized operating parameters and product quality parameters. The cold ceramification technology should prove appropriate for many other DOE complex wastes.

3.1.1.2 Key Problems to be Addressed

Fiscal Year 1999

- A system will be developed and deployed that is adapted to existing Rocky Flats glovebox capabilities, designed to minimize worker exposures, and incorporates capabilities necessary for final product qualification and certification testing.

    - Evaluate laboratory-scale waste forms fabricated with Rocky Flats ash to measure radiolytic gas generation rates and the degree of Pu stability in the ceramic matrix.

    - Evaluate plutonium content required to meet Safeguards Termination Limits.

    - Evaluate applicability of the cold ceramification process to other Rocky Flats residue streams including graphite fines, sand, slag and crucible debris, and other residues with similar attention paid to the development of waste form performance specifications.

    - Characterize the microstructure and mineralogy of the monolith waste form.

Fiscal Year 2000

- Extend deployed technology to stabilize fission products and Pu species from electrorefiner separation techniques. The combination of electrorefiner precipitation and cold ceramification will extend the applicability of this technology to many more DOE Complex wastes, particularly the large inventory of difficult to treat salts.

- Address issues related to process chemistry, waste prehandling, and post stabilization characterization needs of other waste streams.

- Develop and deploy a mobile cold ceramification mixing unit.

3.1.1.3 Site Buy-In. Primary Rocky Flats managing contractor Kaiser-Hill has recently completed a cost/benefit analysis comparing the chemically bonded cold ceramification process with the existing baseline stabilization method of vitrification. The results of that analysis are very promising and indicate a $10M cost savings and a 9-month schedule improvement with cold ceramification. These results were forwarded to the Rocky Flats Field Office in a February 26, 1998 memo. At KH-Rocky Flats, contact Ken Ferrera (303.966.4436) or Bob Leonard (303.966.4889).

3.1.1.4 STCG/DOE Strategic Needs. The cold ceramification project was initiated to support Rocky Flats accelerated cleanup goals and directly respond to DNFSB 94-1 requirements. In so doing, development of the cold ceramic stabilization technology addresses STCG need RF-SNM04, "Residue Processing Technologies," presently ranked 6th in priority out of 45 special nuclear material needs at Rocky Flats. The PFA will continue to work closely with Rocky Flats to develop a complete process implementation system which incorporates methods for characterizing residue processes at the time of stabilization to allow simplified and cost effective certification of final products for interim safe storage or WIPP disposal (RF-SNM03, "Characterize Residue Treatment Process," 21 out of 45 Rocky Flats SNM STCG needs). Through the cross-cutting implementation of robotic technologies in the engineering design of a Rocky Flats deployable cold ceramification, this process may be implemented at a significant reduction in worker exposures (RF-SNM07, "Improved Radiation Control Engineering Technology," 37 of 45 RF-SNM STCG needs).

3.1.1.5 Cross-Cutting Initiatives

Robotics Collaboration—Remote Operations For Ceramics Mixing. Cold ceramification is a strong candidate technology to stabilize several residue streams recommended for stabilization by the DNFSB Recommendation 94-1. Many of these residues could contribute to undesirable worker doses in the most direct application of the technology, i.e., hands-on in a glovebox system. Therefore, developing remote capabilities for batch mixing application of the cold ceramic technologies will enable low-cost stabilization of high-energy residues while minimizing worker dosages.

University and Scientific Programs—Moisture Retention in Phosphate-Bonded Ceramics. The characterization of water distribution and structure in cold ceramics is needed to advance application of this very promising stabilization technology to varied radioactive wastes and residues in the DOE complex. Initial interest in water characterization stems from the need to distinguish structural versus excess water presence and distribution. Studies of radiolytic gas generation rates from cold ceramics indicate differences in hydrogen release rates based on structural versus pore water distributions. As the goal is to produce waste forms with minimal gas generation threats, understanding the water distribution and, in turn, using that information to tailor the process to most desired performance is essential. Further application of cold ceramification to more problematic wastes may require dehydration of the final crystalline matrices. This work will serve as the basis for considering waste form alterations in such applications.

3.1.2 Encapsulation of HEPA Filter Medium (FY 2000)

3.1.2.1 Project Summary. The INEEL's site treatment plan (STP) includes many proposed treatment technologies for INEEL generated or stored filters containing plutonium. They include leaching, incineration, macroencapsulation and others. However, all proposed technologies have major drawbacks. Examples include:

- Incineration of glass-fiber filters that do not contain organics is not accepted by the Environmental Protection Agency (EPA). The EPA views incineration of waste containing only inorganic constituents to be impermissible dilution

- Filter leaching generates large volumes of acidic waste which will require further treatment,

- Macroencapsulated filters may still require management in a RCRA sub-title D facility.

All of these proposed treatments increase the original volumes of waste, generate secondary waste streams that will require treatment, or generate a waste form requiring further regulated management.

Filters typically are made of fiberglass filter media and, after use, contain transuranic and other radioactive elements and a host of RCRA characteristic toxic metals as contaminants. In some cases the filters may also be contaminated with RCRA "listed" waste. Preliminary laboratory tests have found that the fiberglass filter media melts at temperatures below 845°C and can be vitrified in a low-melting glass flux. Metals contained on the filter media such as cadmium, lead, silver, barium, molybdenum, zirconium, strontium, and cesium were retained in the glass disk. This project expands the technical knowledge and develops a process that can be deployed.

This process has several advantages over the currently planned treatments. First, melting the filter into a flux will reduce its volume dramatically with no secondary waste streams. Second, dissolving the melted filter media will remove any interstitial areas that may contain loose particulate. This is expected to produce a uniform glass-like waste form. Third, numerous filters may be processed until the receptacle is filled to capacity. The receptacle containing the solidified media will be removed and placed in a 55-gallon waste drum for transportation and disposal. Finally, the equipment required is minimal and can be operated with little chance for system upsets or breakdowns. The proposed flux, lithium metaborate flux, is typically used in analytical laboratory analysis with quantitative retention of RCRA toxic characteristic metals. The temperatures are sufficiently low to minimize volatilization of most inorganic elements and RCRA metal volatilization should be insignificant. The program will extend the laboratory bench tests to a full scale demonstration.

3.1.2.2 Key Problems to be Addressed

Fiscal Year 1999 and 2000

- Equipment design for removing the filter media from the frames.

- Testing to show that the aluminum ribbing may be readily melted at the proposed processing temperature of 800°C, and readily incorporated as alumina in the glass matrix.

- Development of a gentle thermal microencapsulation method to treat filters containing only inorganic contaminants melting the filter media into a glassy matrix resulting in the immobilization of the RCRA metal and radionuclide contaminants will be evaluated. For filters containing organic contaminants or a combination of organic and inorganic contaminants the above method will immobilize metals while thermally extracting the organic contaminants from the filter media which will then be destroyed in the off-gas stream using a secondary thermal destruction device.

- Development of a Fourier transform infra-red spectrometer will be used to provide feed back to control the rate of soot generation by monitoring carbon monoxide emission with respect to time. The soot will be oxidized using an air inductively coupled plasma that is sustained by the air used to purge the casement.

- Evaluate the efficiency of the plasma-based off-gas unit and trapping process.

- Characterization of the glass monolith to evaluate metal loading in the glass, porosity, optimize flux to filter ratios, and the retention of EPA toxic characteristic metals, actinide elements, Cs, Sr, Re and Y.

- Complete full scale tests using actual filters to determine if the process is feasible for use. An experimental design will be formulated to optimize the process for the larger-scale system.

3.1.2.3 Site Buy-In. Research and development of a more efficient filter treatment process would benefit the INEEL and ANL in reducing or eliminating the backlog of filters in storage. The INEEL alone has 101.5 m^3 of filters in storage with another 34 m^3 projected to be generated over the next five years. Many of these filters may be treated more efficiently using the technology proposed. ANL has accepted this encapsulation as a desirable filter disposition option.

Other laboratories will benefit from this technology. FY 1999 planning includes obtaining site buy-in wherever there is a large inventory of contaminated filters.

3.1.2.4 STCG/DOE Strategic Need Ties. This research initiative is consistent with needs expressed by the RFETS STCG need RF-DD11, "Size Reduction of Contaminated Equipment and Demolition Waste." The needs statement however, is more orientated to glovebox, piping, equipment, and furniture, etc. HEPA filters will be generated in copious quantities during the decontamination and decommissioning process at Rocky Flats. This is in addition to the existing quantity of filters currently in storage. This process may lead to a stabilized wasteform that is not "diluted" in a conventional melter, but is the major constituent of the waste form. Volume reductions for the media are predicted to be greater than 20 fold.

3.1.2.5 Cross Cutting Initiatives. Characterization Monitoring and Sensor Technologies Program. This program can use technologies that are currently being evaluated in the CMST program for metal detection in particulate using two technologies currently being evaluated, namely air-inductively coupled plasma—atomic emission spectrometry and laser induced breakdown spectrometry.

3.1.3 Miscellaneous Residue Stabilization Needs Assessment (FY 1999)

3.1.3.1 Project Summary. Inventories of plutonium residues not included in the major trade studies (38MT material containing about 500 kg plutonium) have no clearly identified path forward; that is, no trade study has been chartered to address all pertinent issues leading to disposition. This project would address this stabilization gap.

Miscellaneous plutonium residues include insulation, ceramics, scrap metals, fire brick, and LECO crucibles. The majority of these residues are held at RFETS in 30 item description codes. Additional inventories are held at Hanford and at other sites. Some of these residues such as LECO crucibles contain plutonium in a nearly irrecoverable form, and as such are possibly, sufficiently stable to readily dispose at WIPP. Graphite fines represent a category of residues requiring research and development before it can be dispositioned.

The 1997 revision of the Research and Development Plan concluded that a comprehensive assessment of the residue inventories is needed to determine if there are miscellaneous inventories that cannot be treated by technologies being developed for other residues, or by straight forward repackaging and disposal.

It is anticipated that a comprehensive assessment would be similar in scope to the other major Trade Studies. It is estimated that the assessment will require about six months to complete. Selected technologies would be developed in late FY 1999 and beyond for the application at RFETS and other sites. Only technologies already at Gate 3 (technical materials < 5) are expected to be considered.

3.1.3.2 Key Problems to be Addressed

- Complete a Trade Study to address a path forward for plutonium residues not included in existing trade studies.
- Recommend a path forward for these residues. The Trade study will involve RFETS, Hanford, and other sites. Consensus would be reached on the next step to disposition the major portion of these residues.

3.1.3.3 Site Buy-In

- RFETS, Hanford, and others involved would be brought into the trade study. The recommended Path Forward would have buy-in from these sites.

3.1.3.4 STCG/DOE Strategic Need Ties. Identified in 1997 R&D Plan for RFETS Disposition.

3.1.3.5 Cross-cutting Initiatives. None.

3.1.4 $CaCl_2$ Detection (FY 1999 and FY 2000)

3.1.4.1 Project Summary. A simple quick technique is needed to determine the presence of $CaCl_2$ in pyrochemical salt residues. The baseline for many pyrochemical salts (NaCl/KCl) is salt distillation. A large percentage of the item description codes of the RFETS salt residues have been found to contain $CaCl_2$ which cannot be successfully distilled using current equipment or technologies. This work will focus on a screening technique that can be used easily and effectively in the pyro-oxidation furnace glovebox system.

3.1.4.2 Key Problems to be Addressed

- Identify a simple, and quick analytical technique to screen pyrochemical salts for the presence of calcium chloride.
- Demonstrate that a commercial system can perform acceptably and can be accommodated in the process glovebox.

3.1.4.3 Site Buy-In. The PFA TAP endorsed the task to demonstrate a working system.

3.1.4.4 STCG/DOE Strategic Need Ties. A solution is needed to enable accelerated RFETS site cleanup and closure.

3.1.4.5 Cross-Cutting Initiatives. None.

3.1.5 Plutonium Characterization using Nuclear Magnetic Resonance Spectroscopy (FY 1999 & FY 2000)

3.1.5.1 Project Summary. Instrumentation will be developed and deployed to characterize water and corrosive content in plutonium-bearing materials including oxides and ceramic monoliths. The technology, Toroid Nuclear Magnetic Resonance Spectroscopy (NMR), was recently developed at ANL and received an R&D 100 award. The technology, when extended to plutonium bearing material characterization, would provide more comprehensive and more relevant data than LOI testing, neutron-based characterization techniques, or super-critical CO_2 extraction. Engineering-scale characterization devices will be constructed and deployed for Pu-bearing material characterization.

Currently, the Department of Energy has plans to stabilize, package, and store a significant quantity of Pu-bearing materials in packages meeting DOE-STD-3013-96. Recent estimates of the number of plutonium packages requiring opening and repackaging exceed 10,000. An important step in this process is the nondestructive determination of moisture and trace corrosive material content before packaging. If moisture is not properly driven from the Pu prior to packaging, then oxidation in the package may occur because of the reaction $PuO_2(s)+xH_2O(adsorbed)=PuO_2+x+xH_2(g)$ (x=1,2) resulting in package pressurization. It may also be important to determine the content of trace corrosive materials in order to maximize the shelf life of the packaged materials. Present techniques, e.g. LOI testing, neutron thermalization, neutron scattering, and supercritical CO_2 extraction yield inconclusive or misleading results, which may not possess the necessary sensitivity to adequately characterize Pu bearing materials, or do not provide information on other isotopes of interest. Toroid NMR Spectroscopy has provided a highly sensitive, robust means of quantifying and mapping moisture, trace corrosive content, and other nuclei of interest in uranium oxides. It is anticipated that it would also demonstrate a high degree of sensitivity in measuring moisture and other NMR sensitive nuclei contained in plutonium bearing materials.

3.1.5.2 Key Problems to be Addressed

Fiscal Year 1999

- Determine sensitivity of Toroid NMR spectroscopy to identify, quantify, and map corrosive nuclei in Pu oxides and ceramic monoliths.
- Determine feasibility of characterizing phosphate ceramic monoliths made from Rocky Flats ash.
- Develop instrumentation to detect, quantify, and map locations of water content in Pu oxides and ceramic monoliths to 0.005 w/0.

Fiscal Year 2000

- Develop and deploy instrumentation for isotopic characterization of Pu-bearing materials.
- Deploy instrumentation to detect, quantify, and map locations of water content in Pu oxides.

3.1.5.3 Site Buy-In. Developers of the phosphate ceramics process, proposed as a stabilization technique for RFETS ash, have indicated interest in using NMR to characterize the ash monoliths. Further site buy-in will be obtained in early FY 1999, immediately following device characterization testing.

3.1.5.4 STCG/DOE Strategic Need Ties. Development of advanced NMR systems for field deployment may directly address STCG needs at the SRS (SR-1003—Characterizing of radionuclide constituents and concentrations, and the RCRA constituents and concentrations including metals, volatiles and semi-volatiles; SR-5003—Provide safe, cost-effective, long-term storage for stabilized materials); at the Rocky Flats Site (RF-WM04—Improved sensitivity for Plutonium non-destructive assay instrumentation and disposal and RF-SNM03—Characterize Residue Treatment Process); and at the Oak Ridge Site (ORO-WM-14—Assessment of Long-Term Performance of Final Waste Forms, ORO-WM 17—Characterization of Heterogeneous Wastes).

3.1.5.5 Cross-Cutting Initiatives

University And Scientific Programs—Sensitivity Analysis/Process Design. Toroid NMR is a relatively new NMR technique that has shown a high degree of potential when applied to small assay samples. A rigorous analysis will need to be performed to determine the sensitivity of the technique when applied to larger assay samples to be encountered in field deployed systems. An opportunity exists to collaborate with top NMR research universities to study the issues of large sample sensitivity and determine which nuclei the technique would be able to quantify in various assay sample matrices.

Industry Collaboration—Engineering Scale System Design. Conventional NMR assay systems are presently used for a variety of applications including medical and biological imaging and analysis, assay of agricultural products, structural inspection of aircraft, and rocket fuel tank inspection, to name a few. The potential exists to tap this industry expertise to expedite the design and deployment of a toroid NMR system for nuclear material assay. Collaboration between government laboratories, universities, and industry should be established to minimize the time to deliver a field-deployable system.

3.1.6 Salt Distillation (FY 1999 & FY 2000)

(A parallel technology has been funded.)

3.1.6.1 Project Summary. Over 18 metric tons (16 at RFETS and 2 at LANL) of pyrochemical salt residue is in storage within the DOE complex. These salts are considered unacceptable for safe interim storage, as specified in DNFSB Recommendation 94-1. The disposition of pyrochemical salts was studied as a result of the Pyrochemical Salts Trade Study, and later with the RFETS rebaselining exercise. The rebaselining effort concluded that ER and MSE salts would be stabilized by pyro-oxidation, followed by salt distillation for those items that exceeded the 0.2 wt% Pu allowed under the safe guards termination limits.

Pyro-oxidation converts the salt inventories to a stable form; however the plutonium content (above the STL limit of 2 g Pu/kg salt) and ease of plutonium recovery may preclude direct disposal of the stabilized salt at WIPP. The RFETS rebaselining effort defined salt distillation as the preferred technology for separating plutonium from ER and MSE salts that do not meet STLs for WIPP. A number of activities have been requested by RFETS to support this effort. An additional problem is the identification of pyrochemical salts that have been improperly labeled and contain $CaCl_2$. Unlike NaCl/KCl salts, $CaCl_2$ will not distill within the operating temperature and pressure of the distillation unit. An analytical technique to make this determination without removing a sample from the glove box line may be required to sustain anticipated process rates.

3.1.6.2 Key Problems to be Addressed

- Evaluate applicability and test salt distillation process equipment used successfully with uranium bearing salts.

- Test the performance of alternative oxidants to more effectively separate salt from the plutonium residues.

- Perform engineering design evaluation to adapt current distillation units to RFETS facility process lines.

3.1.6.3 Site Buy-In. The primary RFETS managing contractor, Kaiser Hill, has adapted pyro-oxidation and integral salt distillation for MSE and ER salts with a second prototype being tested at LANL. Because of remaining uncertainties, Kaiser Hill supports testing by others to resolve the uncertainties. As a back-up, Kaiser Hill may only pyro-oxidize the salt residues and then ship them offsite for final disposition.

3.1.6.4 STCG/DOE Strategic Need Ties

3.1.6.5 Cross-cutting Initiatives

3.1.7 Ceramics for Plutonium Halide Residues

3.1.7.1 Project Summary. As part of plutonium fluoride conversion, plutonium metal reduction and plutonium purification processes performed at RFETS and LANL, and residue salts containing various concentrations of plutonium halides (such as plutonium tetrafluoride) were generated. These residues need to be stabilized for final disposal.

A zeolite-based, ceramic waste form was developed for the disposal of transuranic and fission product halides from the electrometallurgical treatment of spent nuclear fuel at ANL. In this process the bulk of the fission products and actinides, including plutonium, form chloride salts. For disposal as a high-level waste, these salts are occluded into anhydrous zeolite which is subsequently mixed with glass frit and converted into the stable mineral sodalite using a hot isostatic press. The monolithic sodalite waste form has been demonstrated to have excellent retention of transuranics and fission products chlorides.

For this project, waste processing technology from the electrometallurgical technique would be expanded to include stabilization of other transuranic halides with emphasis on plutonium tetrafluoride. Process adaptation and feasibility testing would be the focus of initial work.

3.1.7.2 Key Problems to be Addressed

Fiscal Year 1999

- Determine compositions and quantities of plutonium residue salts that are candidates for stabilization using zeolites.

- Modify existing flowsheet to accommodate plutonium residue salts. Initial focus would be on PuF_4.

- Perform preliminary safety analysis of treatment method for plutonium residue salt with emphasis on neutron generation from alpha-neutron reactions due to the presence of fluorine.

- Modify and fabricate equipment for glovebox production of ceramic waste form samples containing simulates for plutonium residue salts.

- Start feasibility testing by producing ceramic waste form samples containing simulates for plutonium residue salts.

Fiscal Year 2000

- Complete feasibility testing and production of ceramic waste form samples containing simulates for plutonium residue salts.

- Perform characterization studies of ceramic waste form samples containing simulates for plutonium residue salts.

- Develop a glovebox system for deployment to treat existing plutonium residue salt.

3.1.7.3 Site Buy-In. Early FY 1999 will be used to elicit input, support, and collaboration for this project from other DOE complex sites.

3.1.7.4 STCG/DOE Strategic Needs. This work is in direct support of STCG need RF-SNM04, Residue Processing Technologies. This need was site priority 6 of 45 and was 2 of the 12 SNM needs. As noted in the Draft EIS on the Management of Certain Plutonium Residues and Scrub Alloy Stored at the Rocky Flats Environmental Technology Site, there are a number of different plutonium fluoride residues for which stabilization technologies are needed.

3.1.7.5 ***Cross-Cutting Initiatives.*** None are proposed at present.

3.1.8 Stabilization of Zero Power Physics Reactor Plutonium

3.1.8.1 Project Summary. The Zero Power Physics Reactor (ZPPR) is a critical-experiment facility at ANL-West in Idaho. It is presently in standby mode, and its lightly irradiated fuel is considered excess SNM. A large fraction of the fuel materials are plutonium-depleted uranium alloys. Most of these materials contain molybdenum, though some are aluminum alloys. As excess SNM, they may be immobilized and disposed of using the can-in-canister (CIC) concept. With CIC, the plutonium will be converted into a ceramic material and placed on a rack system in a stainless-steel canister which will be filled with glass high-level waste (HLW). Canister filling with HLW will occur at a facility like the Defense Waste Processing Facility at SRS. This project proposes to examine using the electrometallurgical treatment process that was developed for conditioning spent nuclear fuel to convert the ZPPR fuel material into an acceptable ceramic form for the CIC concept.

With the existing electrometallurgical treatment process, alloyed uranium and plutonium fuel are dissolved into a LiCl-KCl based electrolyte. The uranium, transuranics, and the bulk of the fission products form chlorides. The uranium which constitutes the bulk of the feed can be removed as low-enriched or depleted uranium. A zeolite-based ceramic waste form has been developed for the disposal of the transuranic and fission product chlorides. For disposal as HLW, these materials are occluded into anhydrous zeolite which is subsequently mixed with glass frit and converted into the stable mineral sodalite using a hot isostatic press. The monolithic sodalite waste form has been demonstrated to have excellent retention of transuranics and fission products.

For this project, waste processing technology from the electrometallurgical technique would be expanded to include stabilization of plutonium from ZPPR. Work would focus on dissolution of the fuel into the electrolyte and on waste form production. Process adaptation and feasibility testing would be the focus of initial activities.

3.1.8.2 Key Problems to be Addressed

Fiscal Year 1999

- Evaluate compositions of ZPPR fuels that are candidates for stabilization by electrometallurgical treatment.

- Modify electrometallurgical flowsheets to stabilize ZPPR fuels for disposal.

- Modify and fabricate equipment for feasibility testing of stabilization technique including plutonium metal dissolution methods and ceramic waste form production.

- Start feasibility testing of stabilization technique.

Fiscal Year 2000

- Complete feasibility testing of stabilization technique including production of plutonium ceramic samples.

- Perform characterization studies of ceramic samples containing plutonium from ZPPR fuels.

- Design production system for treatment of ZPPR fuels.

3.1.8.3 Site Buy-In. The ZPPR fuel plates are stored at the ANL-West site in Idaho. ANL is supportive of this study. Early FY 1999 will be used to elicit input, support, and collaboration for this project from other DOE complex sites. Coordination with the disposition methods for other surplus plutonium would be emphasized.

3.1.8.4 STCG/DOE Strategic Needs. The ZPPR fuel plates are considered excess SNM. This material is different from other types of surplus SNM and may not be compatible with existing disposal options. This work would develop a method for treating this material at its storage site using existing technologies and provide a product that can be shipped and integrated with the rest of the surplus SNM for disposal using the CIC concept.

3.1.8.5 Cross-Cutting Initiatives. None are proposed at present.

3.1.9 Phosphate Extraction and Stabilization of Radioactive Materials from Miscellaneous Residues (FY 2000)

3.1.9.1 Project Summary. The extraction and stabilization of radioactive and fissile materials from the stores of problematic residues found throughout the DOE complex will be addressed in this project. A significant portion of the plutonium bearing residues at Rocky Flats will not meet the

Safeguard Termination Limits (STLs) for transuranic waste drums destined for the Waste Isolation Pilot Plant. Likewise, pyroelectrometallurgical processes within the DOE complex have afforded large amounts of difficult to treat salt residues highly contaminated with transuranics. Finally, there are great concerns to the effectiveness of radioactively contaminated plumes stabilization efforts in groundwater around DOE complex sites.

A great many extremely stable phosphate based minerals are known to be insoluble in water and have recently been found to be insoluble in molten halide salts. In addition, there are an even greater number of synthetic phosphate based materials with these properties, some having the additional property of selective metal extraction/precipitation. This project would use the properties of these phosphates to advantage in a process to extract and precipitate out radionuclides from problematic residues, including molten salts. Considerations for immobilization of contamination plumes in groundwater sources using phosphate precipitation processes can also be undertaken under a broadened scope. Many sites in the DOE complex should benefit from this project.

3.1.9.2 Key Problems to be Addressed

Fiscal Year 2000

- Evaluation of problematic Rocky Flats residues with respect to phosphate extraction and precipitation of radionuclides.
- Evaluation of the extraction and precipitation of transuranic phosphates from molten salts.
- Evaluation of stabilization of precipitates with cold ceramification technology (phosphate bonded ceramics).
- Development and testing of laboratory-scale extraction system. Begin deployment of system at RFETS and SRS or other sites as needed.
- Complete deployment and testing of system at RFETS and SRS.

3.1.9.3 Site Buy-In. Early FY 1999 will be used to elicit input, support, and collaboration for this project from other DOE complex sites.

3.1.9.4 STCG/DOE Strategic Needs. This project addresses the strategic needs of a great many DOE Science and Technology Coordination Groups. This need covers many varied sets of problematic residues. In addition, there are over 35 million gallons of HLW at the Savannah River Site. They document strategic needs for alternate precipitating agents for HLW salt solutions (#SR-2006, Priority 6 of 26) and alternatives to monosodium titanate for alkaline strontium and actinide removal (#SR-2018, Priority 18 of 26). Finally, there are very many STCG needs for groundwater contamination immobilization from virtually every site and well as various miscellaneous aqueous streams.

3.1.9.5 Cross-Cutting Initiatives

Efficient Separations and Processes Collaboration—Extraction and Precipitation of Metal and Radionuclide Contaminants from Aqueous and Non-aqueous Waste Streams as Phosphate Based Materials. The extraction and precipitation of contaminant radionuclides offers the opportunity for significant waste volume reduction. Since a variety of phosphate based materials can form depending on operational conditions, selective extraction may also be attained. The cost savings advantages for such processes are significant.

Cold Ceramification (Phosphate Bonded Ceramics). The compositional similarity between the phosphate based precipitates and cold ceramified phosphate bonded ceramics suggest the production of a superior final waste form. Success in establishing the products from the phosphate extraction and precipitation process as more compatible input forms to the cold ceramification process would allow for the best stabilization product for the varied complex wide waste residue streams.

3.2 Highly Enriched Uranium Stabilization (FY 1999 and FY 2000)

3.2.1 SNM—^{235}U Stabilization

3.2.1.1 Project Summary. Highly enriched uranium (>20% ^{235}U) in any of its physical forms is a primary concern because of proliferation issues and criticality safety issues. The recently completed HEU EIS ROD selected dilution to LEU feed stock (5% enriched in ^{235}U) for LWR fuel fabrication as the best dispositioning option. Material that could not be dispositioned into LEU feedstock is to be disposed of as waste once its ^{235}U enrichment is diluted to 0.9% to preclude proliferation and criticality concerns. Potential dilution/blending processes for waste and "off-spec" HEU include aqueous blending, metal melting, oxide blending, and gaseous blending. Since the majority of the "off-spec" HEU inventory is in the form of solutions, metals and oxides, aqueous blending is the natural selection. However, aqueous processes are no longer available throughout the DOE complex and transfer of existing uranium-oxide materials to an aqueous dilution site is complicated by the receiver's available SNM vault space, the availability of more detailed characterization data and the radiation fields associated with this "off-spec" material. Thus, timely dispositioning of the oxide material is often in question.

The purpose of this project is to develop a new and improved concept of dry milling and blending for diluting waste HEU and "off-spec" HEU oxide with DU or NU oxide to generate an LEU oxide. The proposed mill is based on the principle of a planetary ball mill operation, i.e., a ball mill operating in a very high gravitational field. The RM-2 Concept mill, which is being patented, uses novel but simple mechanical principles to effect and vary the centrifugal field and mill rotation. Feasibility testing with surrogate materials (titanium monoxide blended with titanium dioxide) has produced excellent mixing results. Due to the centrifugal forces, size reduction to sub-micron particles occurs in a matter of an hour. The blending is irreversible and has received a favorable security/proliferation review from LANL. Thus, it appears that this equipment is suitable for blending "off-spec" HEU to <20% ^{235}U enrichment for recycle purposes (i.e., LWR feedstock) or to <0.9% ^{235}U for disposal. Once diluted, the radiation fields from the storage containers will be reduced, the uranium will no longer require the high cost of safeguards protection and the potential for shipping to an "off-spec" aqueous blending site or disposal site will be significantly improved.

3.2.1.2 Key Problems to be Addressed. Evaluate milling and blending equipment with uranium oxide materials to determine blending times, throughput rates, and potential for cross contamination of milling media and uranium and can design to preclude any "dead spots".

- Evaluate the effectiveness of this equipment for blending different oxides (e.g., UO2, U3O8, UO3).
- Evaluate material handling and contamination control issues as related to this specific equipment and the related process steps e.g., adding depleted uranium oxide and enriched uranium oxide to the mixing cylinders, sealing techniques for the storage packages, taking accountability measurements, etc.

3.2.1.3 Site Buy-In. DOE has initiated numerous activities to focus on identifying material management strategies that can integrate resources to reduce operating costs and also accelerate the retirement of facilities and the dispositioning of excess fissile materials, e.g., 94-1 Implementation Plan, 97-1 Implementation Plan, EM Integration/2006 Plan, Processing Needs Assessment study, Nuclear Materials Integration Program, and others. To date, planning strategies have not evaluated this concept of dry milling and blending because it is so new that it has not been identified as a potential blending process. If this technology is proven to be adaptable to dispositioning any of these excess fissile materials, then the dispositioning site would have a non-aqueous option that could be significantly less costly. Dilution to < 20% would also reduce storage costs until such time as the final dispositioning process was implemented. Furthermore, a dry process can be sized to meet throughput rates, is expected to require less operating space and should provide unique schedule flexibility because dispositioning would be decoupled from the retirement of existing aqueous processing facilities (i.e., SRS canyons). The potential use of dry blending is discussed in the document "Feasibility Study for Early Removal of HEU from CPP-651-Phase II" September 1997 INEEL/EXT-97-00977 (contact Roy Campbell, Ph 208-526-1395 or Carie Vitale Smith, Ph 208-526-3887). The results of this study have been discussed with other sites and those contacts include: Oak Ridge (Jim Rushton, Ph 423-576-7000)), SRS (Don McWhorter, Ph 803-952-4547), MD-4 (Dean Tousley, Ph 202-586-0217), EM-66 Hoyt Johnson, Ph 202-586-1019), LANL (Neil Zack, Ph 505-665-5576), University of Utah (Raj K. Rajamani, Ph 801-581-3107) and DP-22 (R. Hahn/Susan Sherwood, Ph 301-903-5250).

3.2.1.4 STCG/DOE Strategic Needs. Contamination control is a significant challenge to any dry process involving radioactive oxide materials. The existence of high-radiation fields when material is being blended presents external personnel exposure issues. Implementing remote handling capabilities for blending the oxide materials and loading them in the dry milling and blending equipment would provide techniques that would help reduce personnel exposure (Improved Radiation Control Engineering Technology, 37 of 45 RF-SNM STCG needs).

3.2.1.5 Cross-Cutting Initiatives. The dispositioning of waste and Off-spec HEU have a common contamination control and radiation shielding issue, i.e. ^{232}U. Small amounts (PPM) of ^{232}U can produce radiation fields that are strong enough to require remote rather than contact handled processes and equipment. Thus, the development of remote handling capabilities to support the principal processing steps (decanning, measuring, milling and blending, packaging, monitoring) is essential to the success of this concept.

SNM accountability measurements must be taken at several steps in this process to assure the HEU has been diluted to LEU concentrations (<20% ^{235}U) or disposal limits (<0.9% ^{235}U).

3.2.2 SNM—^{233}U Stabilization

3.2.2.1 Project Summary. ^{233}U fissile material was not included in the HEU or Pu EIS, but the process of developing a national policy to address such issues as nonproliferation, safeguards and security, environmental and nuclear safety, etc., is underway via the 97-1 Implementation Plan and the Nuclear Materials Integration program. Most of material is at two sites (INEEL and Oak Ridge) and is in the form of oxides and compounds [fabricated Light Water Breeder Reactor (LWBR) fuel rods, pellets and an assembly]. Other forms such as solutions, metals and waste residues make up the remaining inventory and some oxide forms are mixtures of ^{233}U and ^{235}U. Decisions on how much ^{233}U is excess and how best to dispose of any excess material will occur in the near future via NEPA activity. In the meantime, the 97-1 Technical Task Team is developing potential management strategies similar to the dilution theme from the HEU EIS. Isotopic dilution of the ^{233}U with ^{238}U is necessary to significantly reduce proliferation and criticality risks. All of the ^{233}U material contains various amounts of ^{232}U. The decay daughters of ^{232}U emit high energy gamma radiation and therefore typically require radiation protection features (shielding, remote handling, etc.) to maintain ALARA for operations personnel.

This project is an extension of the SNM ^{235}U conditioning described in the previous subsection. If the ^{233}U can be diluted to LEU (<12% 233U) then any continued storage costs can be reduced and the transfer to another site is significantly simplified because the safeguards issues are eliminated. The new and improved concept of dry milling and blending that is under investigation for diluting ^{235}U "off-spec"

HEU oxide to generate an LEU oxide would be extended to ^{233}U materials e.g., oxides and possibly fabricated fuel pellets. The proposed mill is based on the principle of a planetary ball mill operation, i.e., a ball mill operating in a very high gravitational field. The RM-2 Concept mill, which is being patented, uses novel but simple mechanical principles to effect and vary the centrifugal field and mill rotation. Feasibility testing with surrogate materials (titanium monoxide blended with titanium dioxide) has produced excellent mixing results. Due to the centrifugal forces, size reduction to sub-micron particles occurs in a matter of an hour. The blending is irreversible and has received a favorable security/ proliferation review from LANL. When the ^{233}U is dry blended to <12% enrichment, the radiation fields from the storage containers will be reduced, the uranium will no longer require safeguards and the potential for shipping to a blending/dilution site will be significantly improved. Dilution to the disposal threshold (about 0.67% 233U) would reduce these issues even further and may prove to be more cost effective than aqueous blending under consideration at SRS.

3.2.2.2 Key Problems to be Addressed

- Evaluate milling and blending equipment with uranium oxide materials to determine blending times, throughput rates, and can design to preclude any dead spots.
- Evaluate the effectiveness of this equipment for mixing different oxides (e.g., UO2, U3O8, UO3).
- Evaluate material handling and contamination control issues as related to this specific equipment and the related process steps (e.g., adding depleted uranium oxide and enriched uranium oxide to the mixing cylinders, sealing techniques for the storage packages, taking accountability measurements, etc.).
- Evaluate the feasibility and effectiveness of dispositioning fabricated ^{233}U fuel pellets (UO2/ThO2) (e.g., mill and blend fuel pellets with DU oxide to produce a ^{233}U enrichment of < 12% or 0.67%).

3.2.2.3 Site Buy-In. DOE has initiated numerous activities to focus on identifying material management strategies that can integrate resources to reduce operating costs and also accelerate the retirement of facilities and the dispositioning of excess fissile materials, e.g., 97-1 Implementation Plan, EM Integration/2006 Plan, Processing Needs Assessment study, Nuclear Materials Integration Program, and others. To date, planning strategies have not evaluated this RM-2 concept for dry milling and blending because it is so new that it has not been identified as a potential blending process. If this technology is proven to be adaptable to disposition any of these excess fissile materials, then the dispositioning site would have a non-aqueous option that could be significantly less costly. Dilution to < 12% would reduce storage costs until such time as a final dispositioning process is identified and implemented. Furthermore, a dry process can be sized to meet throughput rates, is expected to require less operating space and should provide unique schedule flexibility because dispositioning would be de-coupled from the retirement of existing aqueous processing facilities. The potential use of dry blending is discussed in the document "Feasibility Study for Early Removal of HEU from CPP-651-Phase II" September 1997 INEEL/EXT-97-00977 (contact Roy Campbell 208-526-1395 or Carie Vitale Smith 208-526-3887). The results of this study have been discussed with other sites and those contacts include: Oak Ridge (Jim Rushton, Ph 423-576-7000)), SRS (Don McWhorter, Ph 803-952-4547), MD-4 (Dean Tousley, Ph 202-586-0217), EM-66 (Hoyt Johnson, Ph 202-586-1019), LANL (Neil Zack, Ph 505-665-5576), University of Utah (Raj K. Rajamani, Ph 801-581-3107) and DP-22 (R. Hahn/Susan Sherwood, Ph 301-903-5250)

3.2.2.4 STCG/DOE Strategic Needs. Contamination control is a significant challenge to any dry process involving radioactive oxide materials. This is especially true for ^{233}U which has a higher-specific activity than ^{235}U and is generally considered to present contamination control issues that are more like Pu than ^{235}U. The existence of high radiation fields when material is being blended presents another personnel exposure issue. Implementation of remote handling capabilities for blending the oxide materials and loading them in the dry milling and blending equipment would provide techniques that would help reduce personnel exposure (Improved Radiation Control Engineering Technology, 37 of 45 RF-SNM STCG needs).

3.2.2.5 Cross-Cutting Initiatives. The dispositioning of "off-spec" HEU and ^{233}U have a common contamination and radiation shielding issue, i.e., ^{232}U decay. Small amounts (PPM) of this isotope produce radiation fields that are strong enough to require remote rather than contact handled processes and equipment. Thus, the development of remote handling capabilities to support the principal processing steps (decanning, measuring, milling and blending, packaging, monitoring) is essential to the success of this concept.

SNM accountability measurements must be taken at several steps in this process to assure the HEU has been diluted to LEU concentrations (<12% ^{233}U) or waste (<0.67% ^{233}U). This dry milling and blending strategy may also have some related application for dispositioning Pu oxide materials and special isotopes.

3.3 Russian Collaboration Program (FY 1999 & FY 2000)

3.3.1 Porous Crystalline Matrix for Savannah River Americium/Curium Tank Components (FY 1999 & FY 2000)

3.3.1.1 Project Summary. Approximately 15,000 liters of solution containing isotopes of Am/Cm are currently stored at SRS in F-Canyon Tank 17-1. These isotopes represent a large source term in the canyon. No official decision has been reached if this material should be disposed, or if the material should be immobilized and shipped to ORNL where it would be stored and able to be recovered. The Am/Cm material represents a target material for the production of heavy isotopes such as Cf-252.

The original schedule was to immobilize the Am/Cm solution by direct solidification (vitrification) in a bushing melter commencing in September 1998. Initial failures of the melter pushed the start date to December 1999. Overwhelming technical issues with the melter concerning plugging of the upper plenum and off-gas system caused all R&D efforts (and the concurrent construction effort in the Multi-Purpose Processing Facility) to be placed on hold in November 1997. Rebaselining efforts are under way; current estimates are for a one-to-two-year delay. The liquid fed bushing melter has been dropped in favor of an oxalate precipitation/batch melter process. A new melter technology and alternate glass composition will be required if this path is followed.

These isotopes were recovered during Pu-242 production campaigns in the mid and late 1970s. The storage tank and its vital support systems are old and prone to possible leakage. The Am/Cm has a commercial value and is desired for use by the heavy isotopes program at the Oak Ridge National Laboratory (ORNL). The continued storage of this solution was identified as an item of urgent concern in DNFSB Recommendation 94-1. An analysis of several options has resulted in the recommendation to directly vitrify the Am/Cm solution. However, technical difficulties such as melter damage, foaming, and potential plugging of the off-gas system resulted in significant delays and a change in plans to pursue an alternative vitrification path called the "Batch Process Concept." In this option, the Am/Cm is first precipitated as the oxalate and then vitrified at temperatures near 1,400°C. The Am/Cm would be recovered at ORNL by dissolution of the glass.

The PFA is investigating a technology recently developed in Russia for stabilization of liquid HLW. The technology is based on using a porous crystalline matrix, which absorbs liquids at room temperature. The final waste form is a stable ceramic material, suitable for safe long-term storage and transportation. If a recovery of the isotopes is desired, it can be accomplished by dissolving the ceramic in an acidic solution. In FY 1999, the PFA will establish a joint research program with Khlopin Radium Institute in St. Petersburg, Russia. This program will focus on a demonstration of a crystalline-based matrix for room temperature stabilization of the SRS Am/Cm liquid solution as a possible alternative to the precipitation-vitrification option. The project will test the ability of the porous crystalline materials to trap spiked Am/Cm in surrogate chemical solutions at Russian and U. S. laboratories using lab-scale and scaled-up tests. FY 2000 collaborative implementation tests will be conducted at the Savannah River Site on actual solution if the spiked surrogate solution tests are favorable. The Russian researchers would support full-scale process implementation at SRS.

3.3.1.2 Key Problems to be Addressed in FY 1999

- Evaluate crystalline matrix absorption on test solutions using nonradioactive rare earth elements and uranium as a surrogate for americium and curium.

- Test synthetic solutions with added americium and curium.

3.3.1.3 Key Problems to be Addressed in FY 2000

- Test waste solutions containing actinides including Pu, Am, and Cm.
- Support SRS testing using small scale of actual Am/Cm solution.
- Support SRS in scale-up tests with actual Am/Cm solution.

3.3.1.4 Site Buy-In. If the tests on Am/Cm are promising, this process could be implemented as a low-temperature alternative to vitrification. In addition to the Am/Cm at SRS, the process could also be applied to future plutonium and actinide residue streams arising from decontamination and decommissioning (D&D) activities, such as at Rocky Flats. This process can also support Lead Laboratory waste stream compositions.

3.3.1.5 *STCG/DOE Strategic Need Ties.* NMSTG milestone IP-3.4-015 to start vitrification of Am/Cm solutions at SRS is scheduled for January 2000.

3.3.2 Innovative Plasma Conversion of Plutonium Materials to Oxide (FY 1999 & FY 2000)

3.3.2.1 Project Summary. The ARIES process is currently under development to treat disarmed and partially disassembled weapons components using physical and dry chemical processing to convert the resulting plutonium pits to mixed oxide fuel by first producing a hydride and then an oxide powder. While the processing steps have been demonstrated in glovebox operations and appear to be feasible, there are potential concerns with the use of hydrogen and oxygen and prevention of fires or explosions. In addition, the properties of the resulting plutonium dioxide powder, as related to requirements for the manufacture of mixed oxide fuel, need to be established. Metallurgical work using plasma technology carried out in Russia has recently been described in professional meetings and scientific exchanges. Metallurgical operations included nitrate reduction to form the oxide, preparation of homogeneous, high-grade alloys such as U-Al, and metal oxidation such as Zr or Pu under well-controlled conditions to avoid reactive excursions. Oxidation of uranium metal under air atmosphere has been successfully carried out, and thermodynamic calculations have shown that metallic plutonium and uranium-plutonium alloys will also be oxidized. Processing steps such as removal of gallium or conversion of plutonium metal in pits or in residue to plutonium dioxide could be used in addition to the ARIES process. Thus, this task will evaluate Russian technology that might be applicable to the process for converting plutonium weapons components and residues to plutonium dioxide suitable for mixed oxide fuel manufacture. The tasks will evaluate the feasibility for U. S. materials based on a review of the Russian experience with similar materials and on selected feasibility tests. If the proposed process proves to be feasible, a research plan will be developed for larger-scale tests to develop a design for full-scale implementation.

3.3.2.2 Key Problems to be Addressed in FY 1999

- Test plasma conversion process using uranium as a surrogate for plutonium.
- Test plasma conversion process using plutonium fluoride.

3.3.2.3 Key Problems to be Addressed in FY 2000

- Perform scale-up tests using uranium.

- Perform scale-up test with uranium-plutonium fluoride mixtures.

- Test oxide powder for preparing MOX pellets.

3.3.2.4 Site Buy-In. This project supports the LANL mixed oxide (MOX) Lead Lab development as a non-aqueous alternative to the ARIES process under the DOE Office of Fissile Material Disposition.

3.3.2.5 STCG/DOE Strategic Need Ties. The Record of Decision (ROD) on disposition of weapons materials indicates that the MOX option was preferred for materials that were suitable and vitrification for materials not suitable for MOX. This project supports an alternative approach to the current baseline.

3.4 Packaging and Storage Technologies

3.4.1 Integrated Monitoring and Surveillance System (FY 1999 and FY 2000)

3.4.1.1 Project Summary. The Integrated Monitoring and Surveillance System (IMSS) project provides a complex-wide resource for process definitive testing of sensor, measurement, and process integration technologies necessary for the monitoring and surveillance of SNM contained in short, intermediate, and long-term storage configurations. Sites that either could or are currently benefiting from this resource include SRS APSF, the Hanford Nuclear Reservation, RFETS, ORNL, and sites throughout the former Soviet Union as well as other facilities under IAEA safeguards. The IMSS project was initiated in December 1996 by the DOE-ID PFA to provide the information necessary for DOE sites to choose amongst alternate monitoring and surveillance technologies. Past experienced has demonstrated that without such predeployment demonstration and evaluation, or Process Definitive Testing, system deployment costs and deployment times can become excessive.

The IMSS presently consists of an evaluation facility, the Safeguard Technology Evaluation Area (STEA) in the Fuel Manufacturing Facility (FMF) material vault at ANL-W, necessary electrical and mechanical infrastructure, data acquisition systems, a wide range of Pu bearing materials, 3013 packages, material packaging systems, nondestructive assay (NDA) systems, prototype storage configurations, and an inventory of sensor systems. These resources provide a capability to mock-up any conceivable nuclear material/package combination and sensor system/storage configuration that may be found in the U.S. or abroad. Transient and static system tests are then performed using packaged nuclear materials, results compared to base-line requirements, and conclusions drawn concerning the adequacy of each system design.

The IMSS project is a joint effort involving ANL and LMITCO. ANL provides overall project management with substantial technical components addressed by both ANL and LMITCO. The IMSS project team is presently evaluating systems developed by several commercial enterprises, Sandia National Laboratory and ORNL. The systems under consideration are to be deployed throughout the DOE complex, FSU nations, Far East, and South America.

3.4.1.2 Key Problems to be Addressed

Fiscal Year 1999

- Integration of IMSS facility and technical resources to optimize deployment of safeguard and monitoring systems at SRS-APSF, RFETS monitoring, and DOE sponsored safeguards and security efforts in FSU nations.

- Process definitive testing of monitoring and surveillance technologies including camera systems, weight sensors, radiation sensors, motion sensors, tamper-indicating devices, and alarm systems under normal and transient conditions.

- Evaluation of integrated monitoring and surveillance systems against derived requirements.

- Development of optimal data integration strategies for system cost reduction/shelf-life extension.

- Provision of analysis data to sites/system developers to maximize safety and minimize cost of deployed systems.

Fiscal Year 2000

- Extension of STEA to include SNM storage locations external to SNM vaults.
- Completion of data synthesis/analysis system for complex-wide deployment.
- Inclusion of U and Np bearing materials in the inventory of packaged materials for evaluation.
- Deployment of robotic capability in STEA and assess value added by robotics in combination with advanced sensor technologies
- Continuation of process definitive testing of monitoring components for DOE complex.

3.4.1.3 Site Buy-In. Several DOE Sites have requested evaluation and/or demonstration of sensor technologies at the IMSS STEA. These include ORNL (Contact: Shirley O. Cox, Program Manager, ORNL-Y-12, Safeguard Storage), Sandia National Laboratory—Albuquerque (Contact: John Matter, Manager, Cooperative Monitoring Systems), Sandia National Laboratory—Livermore (Contact: John Matter, Manager, Cooperative Monitoring Center). Technologies under evaluation and/or demonstration for these sites are to be deployed both nationally, e.g. PANTEX, ORNL, and internationally, e.g. FSU nations, Brazil, Korea, and others. DOE NN-20 has funded a portion of FY 1997 efforts and benefited from the efforts through the incorporation of INEL-751 (Contact: David Crawford, NN-20). Santa Barbara STL assessment (FY 1997) and collaboration for FY 1998 (Contact: Paul Hurley, STL). Evaluations are also underway for private corporations involved in DOE-funded projects including Aquila Technologies (Contact: Steve Kadner), RandTec Corp. (Contact: Jim Harris), and Oxford Instruments (Contact: Rick Seymour).

3.4.1.4 STCG/DOE Strategic Needs. The IMSS project was initiated in direct response to DNFSB 94-1 requirements, specifically to provide the information necessary to choose among alternate monitoring and surveillance technologies. In addition, this project has direct applicability to STCG needs at SRS (SR-5003—Provide safe, cost effective long-term storage for stabilized materials), at the Rocky Flats Site (RF-SNM08—Plutonium interim storage surveillance), and the Oak Ridge Reservation (ORO-WM-27—Enhanced Nondestructive Assay of RH-TRU Waste, ORO-WM-08—Sites Protection Technology for Inadvertent Intruder). The project also could support any other STCG needs indirectly through the assessment of monitoring and surveillance technologies that are developed in direct support of a STCG need. The project also directly supports key DOE strategic initiatives as outlined in the DOE Strategic Plan including National Security Objective 5 "Continue leadership in policy support and technology development for arms control and nonproliferation efforts", Environmental Quality Objective 6 "Reduce the life-cycle costs of environmental cleanup," and Science and Technology Objective 2 "Deliver leading-edge technologies that are critical to the DOE mission and the Nation."

3.4.1.5 Cross-Cutting Initiatives

Robotics Collaboration—Inventory Extension in Large SNM Vaults through Robotic Operation of Remote Monitoring Instrumentation. The trend within the DOE complex is to consolidate SNM inventories in large, central storage locations, e.g. the Actinide Packaging and Storage Facility (APSF) at Savannah River Site (SRS). An opportunity exists to minimize operational costs while maximizing material/package surveillance knowledge through the deployment of advanced sensor technologies. Application of these technologies would necessitate robust interfaces with remotely operated vehicles. A need exists to assess interface and performance issues between robotic manipulation systems and advanced sensor systems. The focus of this effort would be to define potential performance gains and cost savings through the combinations of available technologies. Prototype systems would be demonstrated and evaluated at the Safeguard Technology Evaluation Area (STEA) at Argonne National Laboratory (ANL).

Characterization, Monitoring, and Sensor Technologies Collaboration—In-Situ Pressure Measurements/Monitoring. Significant pressurization of 3013 packages containing Pu is a serious safety issue to be addressed in intermediate and long-term storage vaults. Currently, the pressurization of Pu bearing packages above 100 psi is to be detected through the subsequent deformation of the package. An opportunity exists to investigate the potential of obtaining sub-100 psi pressure indications using remotely operated advanced sensor techniques. The crosscutting collaboration would involve development of in-situ pressure-sensing techniques for incipient, i.e. sub-100 psi detection, and for determination of package deformation. Technologies would be assessed and demonstrated at the STEA at ANL-W.

3.4.2 Storage Containers Fabricated from Radioactively Contaminated Scrap Metal (FY 1999 and FY 2000)

3.4.2.1 Project Summary. The primary goal of the project is to develop the process to fabricate Pu storage containers from radioactive scrap metal, thus reducing a significant waste stream while providing containers needed for short, intermediate, and long-term storage of stabilized Pu. A project to demonstrate the viability of producing 3013 storage containers from radioactive scrap material (RSM) was developed with the assistance of Oak Ridge National Laboratory, British Nuclear Fuels Limited (BNFL) and Oak Ridge Tool-Engineering Corporation. The project will be conducted in conjunction with the DOE Recycling Center for Excellence in Oak Ridge, TN. The primary emphasis for the RSM container project is to demonstrate that radioactively contaminated material that was previous used in the DOE complex can be recycled into new Pu storage containers without jeopardizing the plutonium storage container design, storage, transportation, or inspection requirements. Containers would be fabricated from material removed form the Oak Ridge K-25 facility or the Savannah River Site. Therefore, the need to dispose of the contaminated material would be eliminated. No activated material will be used.

3.4.2.2 Key Problems to be Addressed

Fiscal Year 1999

- The design drawings, specifications, standards, and evaluations for plutonium packaging containers, i.e., residue and 3013, will be reviewed to determine adequacy.

- A value engineering session will be conducted with users and vendors to identify fabrication issues and operability issues. Issues identified with DOE-STD-3013 will be assessed for impacts on the container design. The container specifications will be reviewed and modifications incorporated.

- The RSM material quality will be reviewed and compared to Pu container requirements and limitations identified. The RSM material will be qualified to Pu container requirements. The effect of material contaminants on material quality and container requirements will be assessed.

- Containers will be fabricated from virgin material to verify fabrication process. Destructive analysis will be done to determine quality.

- Containers will be fabricated from RSM and destructively tested.

Fiscal Year 2000

- Prototype containers will be fabricated from RSM material.

3.4.2.3 Site Buy-In. Several sites have requested evaluations and/or demonstrations of radioactive scrap metal reuse. These sites include Rocky Flats Environmental Technology Site (Contact: C. Brown and J. Chapin) and Savannah River Site (Contact: J. Lee)

3.4.2.4 STCG/DOE Strategic Need Ties. Under the FY 1999 Disposition program definition the following was specified: "Develop technologies to fabricate plutonium residue package containers from radioactively contaminated scrap metal...." Additionally, the effort is in direct response and will be worked in conjunction with the SRS STCG Need #SR-4003, "Metal Recycle (Process Equipment, Metal, Steel, and Concrete)"; and Rocky Flats Technology STCG Need # RF-DD12, "Improved Technology for Recycling Radioactive Contaminated Scrap Metal."

3.4.2.5 Cross-Cutting Initiatives

Characterization, Monitoring, and Sensor Technology Opportunity & University and Scientific Programs—RSM Process Monitoring. The RSM melt process will be monitored to assess initial and final radioactive constituents, to determine ability to meet American Society of Testing and Manufacturing (ASTM) certification, and to determine impact of radioactive constituents on final material quality.

University and Scientific Programs—RSM Fabrication/Operability Assessment. Container drawings, specifications, standards, evaluations, and operational procedures/requirements will be reviewed to determine adequacy. A value engineering session will be conducted with users and vendors to identify fabricability and operability issues. Issues identified with DOE-STD-3013 will be assessed for impacts on the container design.

University and Scientific Programs—RSM/Materials Melt Analysis and Improvement. The current RSM melt process and resulting product quality will be reviewed and compared to Plutonium container requirements. Limitations will be identified and process modifications recommended.

University and Scientific Programs—RSM ASME Criteria/Structural Evaluation and Standards Assessment. Container designs and fabrication processes will be reviewed and compared to the American Society of Mechanical Engineer (ASME) Code. Deviations from the code will be identified and design recommendations will be made to bring the design into code compliance. Structural evaluations will be made to support evaluation.

3.4.3 Plutonium Safeguards Data and System Integration (FY 1999 & FY 2000)

3.4.3.1 Project Summary. New nuclear material vaults to be operated within the DOE complex, e.g., APSF, will require significant new data integration and analysis capabilities in order to meet DOE and IAEA reporting requirements. The use of advanced measurement, monitoring, and robotics technologies place this task at the forefront of design and operation considerations due to complexity and data volume associated with advanced monitoring systems. DOE has recognized the importance of this task and issued requests for proposal to address the IAEA data integration and analysis needs for APSF, although no system design has been accepted. The same task must also be accomplished for APSF facility operation, with consideration given to interfacing facility and IAEA systems. Past experience has demonstrated that the lack of appropriate data and system integration significantly slows facility operations and increases facility development and operating costs.

Definition and development of the data collection interfaces will be performed first. The project will scope the integration and analysis system to include appropriate interfaces with the sensor systems. By providing an interface definition between the sensor software and the analysis software, the overall project can be simplified and therefore the schedule accelerated. The data collection network over which advanced monitoring devices operate will then be specified. This will simplify the development of software for sensor communication across the network by standardizing on a single set of protocols. The use of robotic vehicles in the vault and the associated control and data transfer considerations will be addressed. Authentication and encryption of data will also be addressed. Facility/IAEA interfaces for encryption and authentication will need to be given priority. The data/sensor integration system must also provide advanced data analysis tools to minimize facility resource requirements while providing a vehicle to make use of the raw data that will be available. This is important for facility maintenance, material safeguard, and material stability monitoring. Analysis is the weak link in present generation integration and analysis systems. The IAEA has recently identified the need for advanced analysis techniques to transform raw data into comprehensible knowledge as a major area of focus for the coming years. This concern will inevitably impact the DOE complex, making development efforts in this area strategically important.

3.4.3.2 Key Problems to be Addressed

Fiscal Year 1999

- Define IAEA/facility interface requirements using formal systems engineering procedures.
- Define optimal data/system interfaces for facility operations and develop data collection interface definitions.
- Review existing available software followed by software integration and development.

Fiscal Year 2000

- Test and evaluate software tools at the STEA located at ANL-W. Integrate facility personnel feedback into systems.
- Transition integration tools to operational environment at APSF.

3.4.3.3 Site Buy-In. APSF facility designers have recognized the need for these activities (see SP-1 Call for Proposal). However, limited progress has been made. Facility/PFA interfaces will be developed in FY 1999 to demonstrate the cost savings of applying existing PFA resources to the system integration problem.

3.4.3.4 STCG/DOE Strategic Need Ties. In addition to IAEA interface needs (as specified in an IAEA SP-1 in 1997), the project would directly support several SRS STCG needs including SR-5003 (Provide safe, cost effective long-term storage for stabilized materials) and SR-5002 (Develop innovative methods and technology to maximize results with limited funding).

3.4.3.5 Cross-Cutting Initiatives

Robotics Collaboration—Integration of Remote Vehicles into Data Acquisition and Control Systems. Unique integration issues arise from the use of robotic vehicles in SNM vaults. Vehicle control and tracking must be robust and secure. Data transfer via the robot is also a possibility, providing an avenue for remote monitoring of materials. IAEA data tracking issues will also be a concern. These issues need to be addressed for the specific vehicle to be used in the vault.

3.4.4 Plutonium Metal Fire Prediction and Prevention (FY 1999 & FY 2000)

3.4.4.1 Project Summary. A variety of fissile materials in metallic form (U, Up, and their alloys) are currently being stored within the DOE complex, e.g. SRS, RFETS, INEEL, Hanford, ORNL, as unirradiated metals in dry storage or as spent nuclear fuel in both dry and wet storage. Many of these materials have known ignition hazards associated with them, such as pyrophoric uranium and plutonium hydride and plutonium sesquioxide compounds formed during storage by reaction with either liquid water or water vapor. The equation issues become real during IAEA examinations, repackaging, transport, or any other time the material is disturbed from its present condition.

Knowledge concerning the ignition potential of these materials is needed to safeguard against pyrophoric events during the handling of materials, to design safe drying processes for fuels being transitioned from wet to dry storage, to design safe interim storage facilities, and to evaluate repository performance with respect to pyrophoricity hazards uniquely associated with DOE fuels. The array of fuels and storage conditions is so diverse that actual testing of a statistically significant number of these Pu-bearing fuels and materials is not feasible from either an economic or time perspective.

A computer model for predicting the ignition of unalloyed uranium, including the effect of uranium hydride as a pyrophoric initiator, has previously been developed, validated, reported in the literature, and used at several sites. This proposed effort will build upon this work to extend the previous model making it capable of evaluating the ignition potential of Pu and Pu alloys, including effects from the plutonium hydride and sesquioxide compounds that may serve as pyrophoric initiators. Where data is unavailable from the literature, experiments will be performed to measure oxidation rates needed by the model for some of the pertinent alloys. The resulting computer model will serve as a tool for use in evaluating the potential pyrophoric hazards (i.e., metallic fires) associated with Pu and Pu-bearing metal alloys currently stored throughout the DOE complex. This tool will then be made available complex-wide as an aid in prediction and prevention of Pu and U metal fires. Effort during FY 1999 will be directed toward extension of the current uranium model to plutonium and validating the model using data available in the literature. FY 2000 effort will address the issues associated with Pu-bearing alloys, rather than pure Pu metal; collection of some oxidation rate data may be required to support this phase of the model extension.

3.4.4.2 Key Problems to be Addressed

Fiscal Year 1999

- Identification and/or development of mechanistic models for plutonium and plutonium-bearing alloy oxidation.

- Incorporation of the plutonium oxidation model into the existing computer model used for the prediction of metallic uranium ignition (i.e., uranium fires).

- Provision of an analysis tool offering the capability to evaluate plutonium ignition hazards associated with DOE materials.

- Characterization of the availability and condensation attributes of actinide metals.

Fiscal Year 2000

- Performance of necessary experiments to complete model based on customer feedback.

- Extension of predictive model to include Pu metal alloys.

- Provision of analysis tool offering the capability to evaluate Pu and Pu alloy ignition hazards associated with DOE materials.

3.4.4.3 Site Buy-In. Plutonium fires and the resulting damage to DOE facilities have proven catastrophic in the past (e.g., Rocky Flats). Prediction and prevention of plutonium fires, especially for plutonium-bearing materials that may have degraded during storage resulting in the formation of compounds that may serve as pyrophoric initiators, is a need recognized and shared by all DOE sites engaged in material storage.

3.4.4.4 STCG/DOE Strategic Needs. The uranium ignition model development work, upon which the proposed work will build, was initiated at ANL-W as a result of pyrophoric hazards identified with ZPPR "fuel" in dry storage at ANL-W, and EBR-II, and Fermi reactor metallic fuel currently being transitioned from wet to dry storage at the INEEL (ID-1.1.13 and ID-1.1.15). Funding for the previous work has come in part from the National Spent Nuclear Fuel Program (NSNFP). In addition to basic facility operational value (every facility handling metals must consider the metal fire hazard), this project directly supports STCG needs at SRS (SR-1003—Characterizing of radionuclide constituents, SR-5002—Develop innovative methods and technology to maximize results with limited funding, SR-5003—Provide safe, cost effective long term storage for stabilized materials), at RFETS (RF-WM12— Bulk debris characterization techniques) and Hanford (WT009—Representative sampling and associated analysis to support operations and disposal, DD021—Metal decontamination and recycling).

3.4.4.5 Cross-Cutting Initiatives.

University and Scientific Programs—Extension of Uranium Ignition Model to Alloys. Unfunded work is currently underway with a university collaborator, to result in a Ph.D. thesis, associated with the extension of the current uranium ignition model to uranium alloys. Understanding of the mechanistic differences between pure metal and alloy ignition behavior will be directly applicable to the proposed work on plutonium alloys. University and Scientific Programs in the proposed work is desirable.

3.4.5 Intelligent Monitoring System for Safeguards Applications (FY 2000)

3.4.5.1 Project Summary. Application of Intelligent Systems for Safeguards Data Analysis (ISSDA) deals with the knowledge-based computational methods to analyze real-time and historical data from sensor and measurement devices used for the monitoring and surveillance of SNM in short, intermediate, and long-term storage. Unique ANL-W developed computational inference engines and diagnostic tools are leveraged in this work. The primary emphasis of the project is to demonstrate and deploy an intelligent monitoring capability which provides early indications of sensor degradation or failure, material stability problems (e.g., chemical reaction within a fuel storage can), and material tampering or diversion. The systems would reduce life-cycle costs and increase safety and maintainability at SNM storage sites such as SRS, Hanford, and ORNL, as well as reduce site closure costs at RFETS. The systems would also support U.S. efforts to increase nonproliferation efforts in former Soviet states, Russia, and the Far East.

The major justification for intelligent monitoring systems for SNM in storage comes from the projected needs of the IAEA and the DOE through IAEA requirements. As echoed in a recent speech by the IAEA Deputy General, Hans Blix before the IAEA Symposium on International Safeguards in Vienna, October 1997, the current methods of verification and relying on physical access by inspectors are inadequate and labor intensive. In 1996, over 2000 inspectors were deployed and 1.4 million data records were handled. New technologies must be applied to the problem of verification with minimum physical access by inspectors. Blix believes that in the future more reliance on automated techniques for remote monitoring and evaluation/review of collected data is essential. Two key objectives for future systems, according to Blix, is that they be effective (accurate) and efficient (low cost). Effective and efficient safeguard systems can only be effected through a combination of appropriate sensor and surveillance hardware suites and intelligent computer-based monitoring.

The ISSDA project combines the application of advanced data processing techniques to advanced sensor technology. Continual background processing of the sensor data will be performed to detect and characterize off-normal conditions in a prototype SNM storage facility which has been developed as part of the IMSS at the ANL-West facility in Idaho. IMSS provides a unique, DOE complex-wide resource for process definitive testing of state-of-the-art sensor, measurement, and process integration technologies for SNM storage. Both heuristics and statistical analysis techniques will be employed. A knowledge base of heuristics will be constructed by interviewing MC&A and security experts at the ANL-West SNM storage facility. This will provide the "rules" for relating events in time and space to key safeguard scenarios. ANL's multivariate state estimation technique—a patented pattern recognition technique—will be used to calculate the probability that a given sensor reading is accurate. By telling whether there's a true disturbance in the system or merely in the sensor that is monitoring the system, the software reduces the probability of false alarms. The method is far more accurate than setting threshold limits—the conventional way of detecting events that produce alarms.

3.4.5.2 Key Problems to be Addressed

Fiscal 1999

None.

Fiscal 2000

- Storage, retrieval, and real-time processing of data from camera systems, weight sensors, radiation sensors, motion sensors, tamper-indicating devices, and alarm systems under normal and transient conditions.
- Capturing "expert" understanding of relevant processes in a knowledge base of heuristics.
- Developing advanced computational strategies to distinguish between real off-normal events and sensor problems to minimize false alarms.

- Developing of optimal data integration strategies for system cost reduction/shelf-life extension.

- Providing analysis data to sites/system developers to maximize safety and minimize cost of deployed systems.

- Deploying a beta version of the system to the DOE Complex.

3.4.5.3 Site Buy-In. DOE sites with materials under IAEA safeguards would be consulted in FY 1999 to determine specific deployment schedules and needs. However, because of IAEA policy (reflected in the project summary), DOE sites will be required to begin consideration of these techniques.

3.4.5.4 STCG/DOE Strategic Needs. This project has direct applicability to STCG needs at SRS (SR-5003—Provide safe, cost effective long-term storage for stabilized materials), at the Rocky Flats Site (RF-SNM08—Plutonium interim storage surveillance), and the Oak Ridge Reservation (ORO-WM-27—Enhanced Nondestructive Assay of RH-TRU Waste, ORO-WM-08—Sites Protection Technology for Inadvertent Intruder). The project also directly supports key DOE strategic initiatives as outlined in the DOE Strategic Plan including National Security Objective 5—Continue leadership in policy support and technology development for arms control and nonproliferation efforts, Environmental Quality Objective 6—Reduce the life-cycle costs of environmental cleanup, and Science and Technology Objective 2—Deliver leading-edge technologies that are critical to the DOE mission and the Nation.

3.4.5.5 Cross-Cutting Initiatives

University and Scientific Programs—Application of advanced pattern recognition techniques to detect faulty sensors. A major difficulty with automated systems is distinguishing between faulty sensor indications and actually off-normal events. University talent could be applied to develop algorithms to detect sensor faults, thus decreasing system maintenance costs.

3.4.6 Equipment Deployment and Personnel Dose Minimization for Plutonium Handling Systems (FY 1999 and FY 2000)

3.4.6.1 Project Summary. The project provides a decision-making resource for operational analysis of the Plutonium Stabilization and Packaging System to be installed at Building 707 on the Rocky Flats Environmental Technology Site. A discrete event model will be developed and used to estimate operational measures useful for operational analysis, strategic planing, and personnel dose minimization. What-if experiments can be conducted to gain better understanding of critical operations and to estimate operational indices, including throughput, required inventory, bottlenecks, personnel radiation exposure, optimal batch sizes, and equipment use. The decision-making tool can also be used to look at the effects of variations such as labor adjustments, input material composition, and equipment addition, sizing, and downtime. The project will develop a decision-making tool using discrete event modeling of the operations conducted by the Pu SPS in a manner similar to what is routinely applied in industrial manufacturing environments. The central idea is to characterize this complex waste stabilization and packaging process as a collection of interconnected job cells, and then apply operation research techniques to estimate operational measures under several scenarios to produce guidance for improved system operation. The direct benefits of this effort include the development of a tool that can help engineers and managers during system development and operation. For instance, a similar modeling effort was applied to study operation of the Fuel Conditioning Facility (FCF) located at ANL-West Site, where remote handling and processing operations of radioactive material are conducted as part of a spent fuel treatment process. The FCF discrete event model has been used successfully to estimate several operational metrics of this facility, such as throughput, and work distribution, and to assess the predicted benefits of changing current operational practices for improving system productivity and efficiency.

3.4.6.2 Key Problems to be Addressed

Fiscal Year 1999

- Demonstrate utility of technique to candidate sites (RFETS, SRS) using example of deployed models and presently realized cost savings.
- Develop discrete event model descriptive of RFETS Pu stabilization process.
- Perform parametric analysis to determine optimal sequence of processing steps, equipment layout, and material movements such that process line output is maximized and worker exposure is minimized.

Fiscal Year 2000

- Develop discrete event model descriptive of SRS APSF.
- Perform parametric analysis to determine optimal sequence of processing steps, equipment layout, and material movements such that process line output is maximized and worker exposure is minimized.

3.4.6.3 Site Buy-In. Site buy-in will be obtained in early FY 1999 through demonstration of cost reduction realized using currently deployed systems.

3.4.6.4 STCG/DOE Strategic Need Ties. STCG needs directly addressed through this effort include several at RFETS (RF-SNM04, Residue Processing Technologies), RF-SNM03, (Characterize Residue Treatment), and RF-SNM07, (Improved Radiation Control Engineering Technology).

3.4.6.5 Cross-Cutting Initiatives

University And Scientific Programs—Statistical Analysis of Equipment Availability. Monte Carlo models have been shown to be useful in the analysis and optimization of equipment availability in many industrial applications. Performing such modeling of equipment installed to stabilize and package SNM for storage could decrease system down time, thus decreasing project costs. Such models would be created and used to evaluate equipment of interest.

3.5 PFA Management Work Package/Product Line

This product line focuses on management, including strategic approaches necessary to assure the PFA mission and performance objectives for the program are completed successfully. There should be a tie to the Project Baseline Summary (PBS) and the FY 2000 Internal Budget Review (IRB) for the PFA program and will encompass tasks such as Program Integration, Systems Engineering, Technical Resource Team, External and Regulatory, Public Involvement and Stakeholder Involvement. PFA Management will be its own DOE-ID Technical Task Plan (TTP), with a life-cycle planning and funding profile which will include all the tasks referenced above. The following is a brief summary for each task.

3.5.1 Task A: Program Integration

Program Integration will implement and maintain a sound program management process. The approach will be to produce results for an integrated, efficient, and cost effective operational national program providing a performance based platform for the Plutonium Focus Area (PFA). Program Integration will consist of the following subtasks:

3.5.1.1 Subtask A1: Program Control. Responsible for the implementation of project management processes to ensure accountability for program schedule/time management and cost management. All activities are related to cost and schedule, including planning, estimating, schedule development, schedule control, baseline formulation, progress monitoring change control management, and performance measure reporting. This will be accomplished through the development of TTP for each element/task within the PFA WBS.

3.5.1.2 Subtask A2: Program Support. This subtask will provide program support from LMITCO to DOE-ID PFA Program Management. Activities will include Management Oversight, Program Planning, Program Reviews, Federal Budget Cycle, Project Baseline Summaries, Proposal Calls, Internal Review Budget (IRB), Program Execution Guidance (PEG) development, Task Change Control (TCR), Technical Task Plan (TTP) Management and Program Configuration Management including document control. All activities will be performed using sound Project Management processes and principles.

3.5.1.3 Subtask A3: Communication. This subtask will support activities required to assure timely and appropriate generation, collection, dissemination, storage and disposition of program information. This will consist of communication planning, information distribution, performance and achievement reporting, and other information dissemination to include the update/upkeep of the PFA Homepage.

3.5.1.4 Subtask A4: Systems Engineering. Systems Engineering will continue to identify, document, and monitor ongoing and planned technology development activities. PFA systems engineering processes will be used to validate current technologies to EM-30/40/60 needs and requirements, isolate and identify technology gaps, and develop monitor user's defined requirements to assure that technology development addresses and meets plutonium waste stream objectives. Details for the systems engineering approach and procedures are described in the PFA Program Plan (PMP) and the Systems Engineering Management Plan (SEMP). Systems Engineering will ensure that Site Technology Coordination Groups (STCGs) needs are validated to PFA technologies, provide annual processes to allow additions and modifications to needs as required, provide a product and activities to communicate regularly with the STCGs in order to establish priorities, and update the PFA Technical Baseline per their inputs.

3.5.2 Task B: External and Regulatory

The scope of this task is to ensure that environmental regulations will be considered and appropriate regulatory agencies will be consulted on PFA technology development activities. The main purpose of this activity is to ensure that performance requirements are properly isolated and derived from environmental regulations and are considered in the development strategies of the technologies. This activity should also promote regulatory cooperation between states to facilitate permitting of new technologies and ensure that PFA considerations are appropriately included when new regulations are being developed. Basically, ensure that PFA technical products meet regulatory requirements and are permitable by appropriate agencies. Part of this task will include Tribal and public involvement in external communication for any scope of work within the PFA Program that might affect Tribes and members of the public. Issues and concerns will be isolated and the opportunity given to Tribes and the public for inputs to the technical development process. This task will assure that stakeholder involvements are initiated and also part of the technology development process.

3.5.3 Task C: Technical Resource/Management

A Technical Advisory Panel made up of technical subject matter experts (SMEs) will support technical activities as required by the PFA Program. This team will be used as an independent review group for Development Plans, Demo Plans, Test Plans, Deployment/Implementation Plans and any other document which PFA Program Management feels is necessary to ensure that technical development strategies meet users requirements and needs. This team can be used also as an independent consulting team, or in an advisory capacity.

Note: For clarity, this product line is isolated in order to highlight tasks and activities associated with the oversight and management of a national program such as PFA. However, some of these tasks will be part the actual technology development profile, and will be integrated and funded as part of the technology's Technical Task Plan (TTP) submitted through the EM-50 Program Execution Guidance (PEG) cycle. Also, the intent is to maintained the PFA management cost within established funding criteria (5%).

4. BUDGET INFORMATION

PFA FY-1999 –2000

Technology Area	Fiscal Year 1999 Total	Fiscal Year 1999 Cumulative	Fiscal Year 2000 Total	Fiscal Year 2000 Cumulative
Program Management	250	250	375	375
Phosphate Bonded Ceramics	1,100	1,100	1,600	1,975
Integrated Monitoring & System Surveillance System (IMMS)	1,500	2,850	830	2,805
Encapsulation of HEPA Filter Medium	650	3,500	650	3,455
Porous Crystalline Matrix	300	3,800	400	3,855
Storage Containers Fabricated from Radioactively Contaminated Metal	725	4,525	780	4,635
Miscellaneous Residue Stabilization Needs Assessment	275	4,800	0	4,635
Phosphate Extraction and Stabilization	600	5,400	1,150	5,785
$CaCl_2$ Detection	150	5,550	0	5,785
Program Management	125	5,675	350	6,135
^{233}U Stabilization*	550	6,225	250	6,385
^{235}U Stabilization*	650	6,875	250	6,635
Plutonium Characterization using Nuclear Magnetic Resonance Spectroscopy (NMR)	600	7,475	1,500	8,135
Salt Distillation	0	7,475	255	8,390
Innovative Conversion of Plutonium Materials to Oxide	500	7,975	1,150	9,540
Plutonium Safeguards Data and System Integration	230	8,205	230	9,770
Ceramics for Plutonium Halide Residues	0	8,205	730	10,500
Plutonium Metal Fire Prediction and Prevention	377	8,582	350	10,850
Stabilization of Zero Power Physics Reactor Plutonium	0	8,582	625	11,475
Equipment Deployment & Personnel Dose Minimization for Plutonium Handling Systems	250	8,832	500	11,975
Intelligent Monitoring System for Safeguards Application	0	8,832	1,000	12,975

(All Cost X1000)

* If U235 is completed and followed by U233 (or visa versa) the alternative cost would warrant a 250k reduction rather than stand alone costs.

M98054114

Report Number (14) DOE/ID--10631

Publ. Date (11) 199803

Sponsor Code (18) DOE/EM, XF

UC Category (19) UC-2000, DOE/ER

19980720 087

DOE