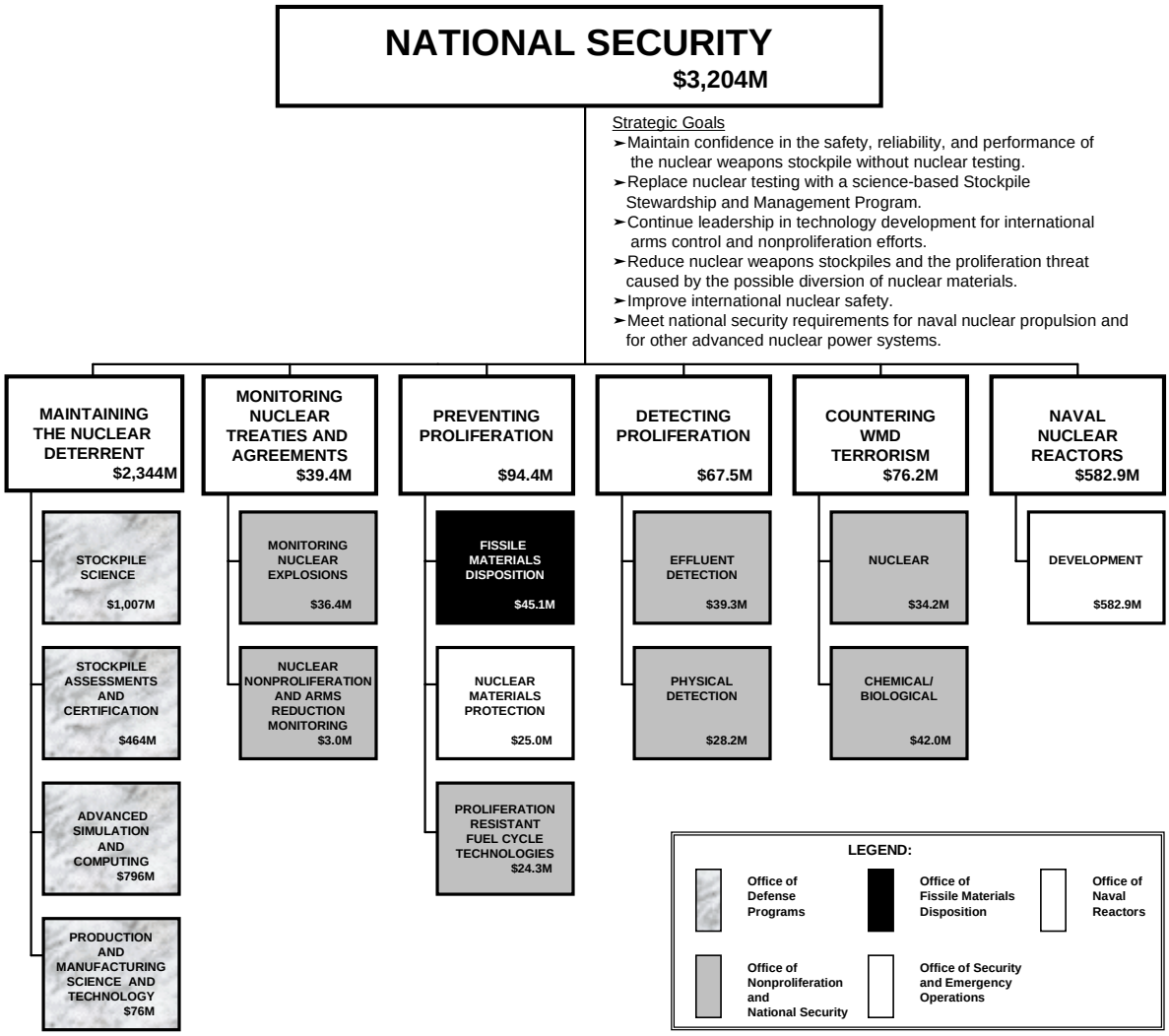
Chapter 5
Preventing Proliferation



Chapter 5
Preventing Proliferation

Table of Contents

Page

Overview 97
Definition of Focus Area 97
National Context and Drivers 98
Linkage to Goals and Objectives 98
Uncertainties 99
Investment Trends and Rationale 99
Federal Role 101
Key Accomplishments 101

Fissile Materials Disposition 102
Background 102
Program Description 102
Pit Disassembly and Conversion 102
Immobilization 104
Reactor Option 105

Nuclear Materials Protection 106
Background 106
Program Description 107
Materials Control and Accountability 107
Physical Protection 110
Information Security 112

Proliferation Resistant Fuel Cycle Technologies 115
Background 115
Program Description 115

Summary Budget Table 119

Overview

Definition of Focus Area

The current environment of warhead dismantlement and decreased requirements for any new weapons leaves the Department of Energy with more nuclear materials on hand than at any time in history. The Department of Energy has an associated responsibility to protect these materials from theft and diversion and to eliminate, where possible, stockpiles of weapons-usable fissile materials through disposition. The DOE research and development portfolio in the area of preventing proliferation addresses: development and adaptation of technologies that convert U.S. weapons-usable materials to a form that will prevent the plutonium from ever being used for nuclear weapons and assisting Russia in the demonstration of plutonium conversion technologies; development of technologies to control and account for nuclear materials and physically protect these materials; and development of proliferation resistant fuel for commercial reactors to reduce and eventually eliminate the international traffic in highly-enriched uranium (HEU) for commercial purposes.

To enable fissile material disposition, necessary process development and tests must be completed to provide the design and operational bases for surplus plutonium disposition facilities. DOE plans to disassemble “pits” and dispose of the surplus plutonium by (1) immobilizing it in a ceramic form surrounded by vitrified high level waste, the “can-in-canister” approach, and (2) by burning it as mixed oxide (MOX) fuel in existing domestic reactors.

Technologies to control and protect nuclear materials must remain state-of-the-art to ensure these materials do not fall into the hands of increasingly sophisticated terrorists. Detection technologies must accurately gauge and quantify mixed-matrix and shielded nuclear materials, while reducing worker exposures. Intrusion detection, barrier and vault systems, as well as countermeasures, must remain effective against continuously emerging threats.

Highly enriched uranium is used peacefully for civil energy production, research, and medical isotope production, but is also used in nuclear weapons. To reduce the danger of proliferation, the United States has pursued the elimination of HEU commerce by striving to develop low enriched fuel suitable for these necessary functions. The fissionable uranium may be able to be ‘diluted’ with non-fissionable uranium to lower the enrichment while maintaining the benefits. Fuel and target fabrication techniques must be developed, and fuel and target qualification tests must be performed to ensure successful performance within reactors.

Preventing proliferation is an area of critical importance to U.S. national security and a high-interest research area for the Department of Energy. The U.S. and Russia have similar interests in and responsibilities for reducing the risk of nuclear proliferation from civilian nuclear power, and both are pursuing technology development programs to accomplish that goal. Continuing interactions with Russian officials on this topic will lead to the identification of many areas where the U.S. and Russian philosophies and technologies contributing to the development of proliferation-resistant nuclear systems will overlap. The Department of Energy intends to accelerate development of proliferation-resistant nuclear systems by implementing a new

research initiative (the Proliferation Resistant Reactors and Fuels Research Program) during FY 2001.

National Context and Drivers

The Department foresees a future national security environment with continued uncertainties and risks of international terrorism from weapons of mass destruction. In the aftermath of the Cold War, significant quantities of weapons-usable fissile materials have become surplus to national defense needs both in the United States and Russia. The threat that nuclear weapons or materials could fall into the wrong hands through theft or diversion is a clear and present danger. The danger exists not only in the potential for proliferation of nuclear weapons, but also in the potential for environmental, safety and health consequences if surplus fissile materials are not properly managed.

United States policy is to protect and control nuclear materials; to seek to eliminate, where possible, accumulation of stockpiles of highly enriched uranium and plutonium; and to reduce and eventually eliminate the civilian use of HEU in research and test reactors and in targets for medical isotope production. The U.S. will also ensure that, where these materials already exist, they are subject to the highest standards of safety, security, and international accountability. DOE is committed to safely dispose of the nuclear materials made surplus by the downsizing of the nuclear arsenal in conformance with arms control and nonproliferation treaty requirements. The Department has developed several strategies that will contribute to a reduction in the global nuclear danger associated with inventories and supplies of nuclear materials that could be used for the proliferation of nuclear weapons.

Linkage to Goals and Objectives

The R& D efforts for preventing proliferation support the Department's national security strategic goal, Objective 4, to reduce nuclear weapons stockpiles and the proliferation threat caused by the possible diversion of nuclear materials. Strategy 2 of Objective 4 would reduce inventories of surplus weapons-usable fissile materials worldwide in a safe, secure, transparent, and irreversible manner. Reducing/eliminating the civilian use of HEU and taking back the spent research reactor fuel from the U.S. and abroad will remove the threat of theft or diversion from these civilian reactors.

Research and development activities for preventing proliferation are also linked to various external requirements as described in:

- Presidential Decision Directives related to preventing proliferation of weapons of mass destruction.
- Highly Enriched Uranium Purchase and Blending Agreement.
- Department of Defense Cooperative Threat Reduction Program (Senate Language).

- Mayak Transparency Mandate from the Biden Amendment.
- Trilateral Initiative.
- Scientific and Technical Cooperation Agreement on the Management of Plutonium That Has Been Withdrawn from Nuclear Military Programs, July 1998.

Uncertainties

The research and development portfolio in this focus area is directed at establishing a technology base to support the design leading to the construction and subsequent deployment of facilities to disposition surplus plutonium. The technical risks corresponding to successfully meeting the goals and objectives of the investment in the portfolio are considered to be manageable. However, the start of construction of the facilities in the United States is dependent on progress on bilateral agreements with Russia for plutonium disposition. Negotiations with Russia are ongoing and agreements may be reached sometime in early calendar 2000. Were negotiations to be suspended the pace of research and development would probably be affected.

Success in converting research and test reactors from highly enriched uranium to low enriched uranium faces technical and political uncertainties. Technical uncertainties relate to the ability to develop and fabricate low enriched uranium fuels and targets with increased density to match the performance levels of higher enriched uranium fuels and targets. The technical risk is considered manageable because of the success of the advanced fuel development work already accomplished. The political uncertainties involve the willingness of foreign research reactor operators to agree to convert to low enriched uranium fuel and targets, as well as the desire of foreign governments to seek to reduce the civil use of highly enriched uranium. The United States attempts to reduce these political uncertainties with incentives and export restrictions.

The eventual success of the Proliferation Resistant Reactors and Fuels Research Program and the pace of successful implementation will be dependent upon the quality of interactions and cooperation with Russian officials. Recent program collaboration discussions have been very encouraging. The program is also dependent upon Russian adherence to their commitments not to sell nuclear technology to Iran beyond that involved in the Bushehr 1 project.

Investment Trends and Rationale

The investments in development efforts are directed at establishing the information that is needed to design and operate facilities to disposition surplus plutonium in the United States. In addition investments are being made in Russia for small-scale tests and demonstrations in plutonium disposition technologies to facilitate Russian decisions regarding plutonium disposition. The Department's current plans are to start design and complete design of U.S. plutonium disposition facilities in the FY1999 through FY2004 time frame. Consequently, the investment is front-loaded to support the design efforts. Some development activities would continue at a lower funding level after the completion of design in order to validate specific process operations.

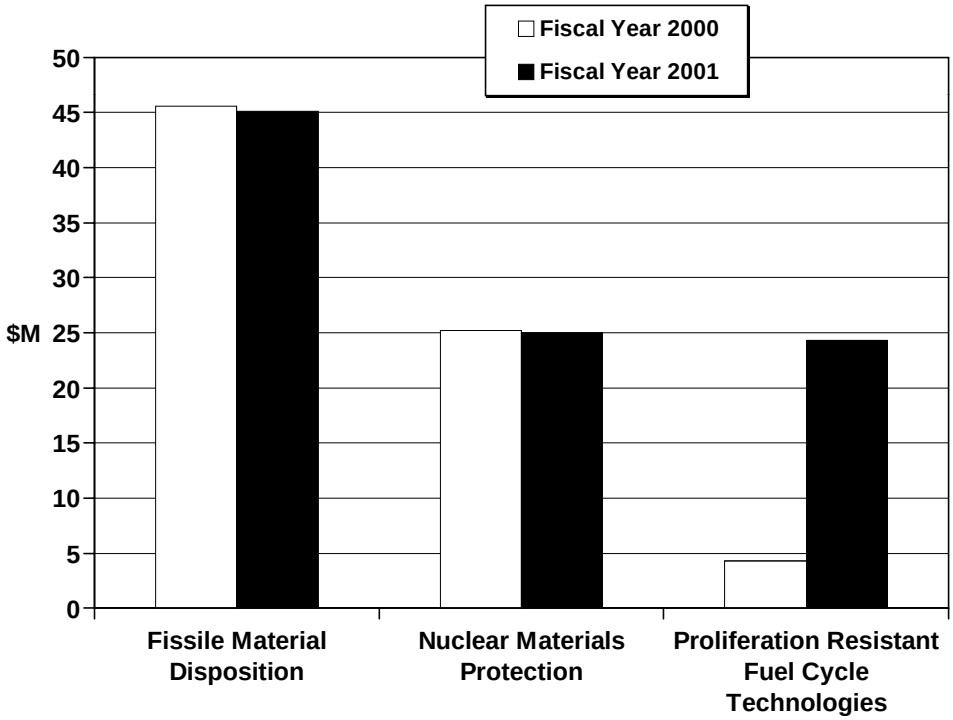
In Russia, the investment is also front-loaded, with most of the investment completed by FY2001. Continuation and expansion of U.S. and U.S.-Russian small-scale testing and demonstration of plutonium disposition technologies is needed to build trust and cooperation and help prepare for reciprocal implementation of future plutonium disposition actions and agreements. This would help fill the gaps in technical knowledge, remove uncertainty regarding the viability of certain technologies, and lead to the successful disposition of surplus plutonium.

DOE executes R&D activities associated with the disposition of surplus plutonium through the expertise and facilities provided at the national laboratories. A lead laboratory is assigned the responsibility for the technical work in a program area. In turn, the lead laboratory contracts with other national laboratories and institutions, such as universities and industry. DOE establishes goals, provides guidance and direction in each program area, and in consultation with the lead laboratory, prioritizes the work and activities in each program area.

The Department of Energy intends to accelerate development of proliferation-resistant nuclear systems by implementing a new research initiative (the Proliferation Resistant Reactors and Fuels Research Program) during FY 2001.

The chart shown below shows investments by activity areas that will be discussed in the remainder of this chapter.

Preventing Proliferation



Federal Role

National Security is a constitutional role of the Federal Government. DOE executes research and development activities associated with the detection of proliferation activities through the expertise and facilities provided at the national laboratories. A single laboratory may manage a program activity area. Alternatively, multiple laboratories may be involved in a program activity area. Inter-laboratory programs are managed from DOE headquarters. In turn, individual laboratories contract with other institutions, such as universities and industry. DOE establishes goals, provides guidance and direction in each program area, and in consultation with the laboratories, prioritizes the work and activities in each program area.

The objective of the Office of Fissile Materials Disposition is to manage, store, and dispose of fissile materials from weapons and weapon programs that are excess to the national security needs of the United States. The Office also provides technical support for Administrative efforts to obtain reciprocal disposition of Russia's surplus plutonium. The head of this office leads these activities and will serve as the Special Negotiator for Plutonium Disposition.

Key Accomplishments

In the area of preventing proliferation, the accomplishments further the technological bases for the design and operation of the disposition facilities. In pit disassembly and conversion, a full-scale demonstration of core functions was designed, constructed, and started at Los Alamos National Laboratory. A number of different pit designs have been disassembled and converted. In Russia, the development of a Russian plutonium conversion and nondestructive assay prototype was initiated and continues. In immobilization, the baseline ceramic form was established and conversion and ceramification equipment was procured in preparation for the integrated demonstration. Cold test pours of simulated high-level waste glass into actual canisters containing cans of simulated ceramic disks verified the feasibility of the can-in-canister approach. Demonstrations of feasibility of several key processes were completed. In Russia, small-scale tests of plutonium vitrification were performed. In the reactor option, the preliminary process parameters for MOX fuel fabrication, using powder derived from weapons plutonium metal conversion, were established. Sample MOX fuel from this process was fabricated, irradiated, and examined.

Accomplishments in materials control and accountability research and development lead to safer inventories of special nuclear materials by furthering the technology base of SNM detection and physical protection. Special nuclear material may now be found in unopened waste drums via non-destructive assay and in vehicles or on persons via enhanced security portals. Remote inventory monitors continue to improve the ability to detect tampering and diversion of SNM while removing the worker from possibly harmful exposures.

Proliferation resistant fuel cycle research and development has demonstrated that all but six western-European high-powered research reactors are able to be converted from using HEU to LEU fuel and, of those that are able to convert, all but ten have plans to do so. The Department

has supported reactor conversion in over 20 countries and has supported the acceptance specification policy in over 40 countries.

Fissile Materials Disposition

Budget: FY99-$43.8M, FY00-$45.6M. FY01-$45.1M

Background

The Department, in a Record of Decision on the Surplus Plutonium Disposition Environmental Impact Statement issued January 2000, announced an implementation approach for the disposition of surplus weapons-usable plutonium in a manner such that these materials can never again be used for nuclear weapons. The Department plans to disassemble "pits" and dispose of surplus plutonium (1) by immobilizing it in ceramic form surrounded by vitrified high level waste, the "can-in-canister" approach, and (2) by burning it as mixed oxide (MOX) fuel in existing, domestic reactors. Pursuing both of these approaches provides important insurance against any unforeseen problems in implementing either approach by itself and provides the United States with flexibility and leverage needed for working with Russia and our allies on the critical task of reducing excess Russian weapons plutonium. Accordingly, the Department's plans include completing the necessary process development and small-scale technology tests, including "can-in-canister" immobilization tests and tests of MOX fuel fabricated from weapons plutonium and subsequent irradiation.

Program Description

For the immobilization approach, the Department needs to resolve the technological issues associated with formulating plutonium in ceramic materials, the production processes, and the impact of impurities on the surplus plutonium forms, in order to have confidence that this approach can provide success in a timely and cost-effective manner.

For the reactor approach, the Department will focus on development tasks associated with handling of the specific plutonium and uranium oxides to be used in fabrication of MOX fuel in order to confirm the applicability of existing fabrication processes and procedures to our mission.

In order to deploy either of these disposition approaches, the Department needs to complete operational testing of the processes that would be used to dissemble pits and convert the plutonium from pits and other forms into a plutonium oxide form which would serve as feed material for both disposition technologies as well as be made available for international inspection.

Pit Disassembly and Conversion

Budget: FY99-$17.9M, FY00-$17.4M, FY01-$15.4M

Description and Objectives. The U.S. activities are to develop, demonstrate and document core functional capabilities required to disassemble surplus weapons pits and convert them to plutonium oxide in a manner as safe, environmentally sound, and cost effective as practical.

Development and demonstration of this process will minimize the cost, schedule, and technical risks associated with the upcoming design, construction and operation of the production facility.

For the Russian effort, the work consists of analyses, and testing as appropriate, of different conversion technologies. The objective is for the Russians to select a pit conversion technology leading to a prototype demonstration of the technology. The Bochvar Institute will do the work, with support from U.S. Department of Energy laboratories.

R&D Challenges. The major overall challenge for the U.S. program is developing a technology that accommodates about 30 unique surplus pit designs, and keeping the process robust and cost-effective, while minimizing operator radiation exposure. The challenge in Russia, is the selection of a conversion technology that the Russians can readily deploy.

R&D Activities. The major R&D activities involve the testing of a prototype demonstration at Los Alamos National Laboratory that will provide the process parameters for and operating experience in several core modules. Activities include: development of an optimum joint pit disassembly /plutonium extraction and conversion approach; development of a plutonium oxide long-term packaging and non-destructive assay (NDA) system; development of a non-plutonium pit part disposition approach; and development of robotics for the above functions. For work in Russia, the goal is for the Russians to select a pit conversion technology leading to a prototype demonstration of the technology. Each of these areas is described below:

- **Development of an Optimum Plutonium Extraction and Conversion Approach**—A pit bisector module coupled with a pyrochemical plutonium metal to plutonium oxide conversion module will be operated to obtain operating process parameters.

- **Development of a Plutonium Oxide Packaging and Non-Destructive Assay System**—The basic functions of plutonium oxide canning have been manually demonstrated on a number of pits. Then the canning system will be automated and the automated canning and NDA system will be demonstrated on the remainder of pits to be processed in the demonstration activity, covering all surplus pit types.

- **Development of a Non-Plutonium Pit Part Disposition Approach**—Pit disassembly results in numerous unique pit parts which require development of particular process steps for disposition. Development involves establishing processes, equipment, and procedures for disposition of particular pit parts, such as for the decontamination of uranium hemishells and the declassification of non-Special-Nuclear-Materials hemishells.

- **Development of Robotics**—Several of the process steps are being automated to reduce the radiation exposure to operators. Robots are being fabricated and will be tested in a glove-box environment.

- **Russian conversion**—The options for the conversion of Russian surplus weapons plutonium will be analyzed, and the technology selected will be developed and tested in Russia.

Accomplishments

- Completed an initial integrated pit disassembly and conversion demonstration run with a full scale demonstration system of core functions at Los Almos National Laboratory.
- Operated a full-scale glove box modules for pit bisection and plutonium oxidation at Lawrence Livermore National Laboratory.
- Disassembled and converted plutonium from 12 of 30 different types of surplus pits.
- Cold-test demonstrated robotics for the plutonium oxide packaging system.
- Initiated development of a Russian plutonium conversion and nondestructive assay prototype system.

Immobilization

Budget: FY99-$16.5M, FY00-$21.8M, FY01-$21.6M

Description and Objectives. The U.S. activities are directed at resolving technological issues associated with immobilizing plutonium in a ceramic. Research and development is being conducted to establish the process, and associated parameters, and develop and define the equipment that will support the deployment of the can-in-canister immobilization technology.

For the Russian effort, the work consists of experiments involving the immobilization of plutonium in glass and ceramic matrices. The objective is to demonstrate to the Russians that immobilization can be used for plutonium disposition, even if only for waste streams from the disposition facilities. This work is conducted at the Bochvar Institute and Radium Institute in Russia, with support from the DOE national laboratories.

R&D Challenges. Challenges include developing a product and technology that accommodates the full range of impurities and constituents in the non-pit surplus plutonium while keeping process and equipment simple, flexible, cost effective, and low radiation exposure to operators. The challenge in the Russian program is to convince Russia that recovery of plutonium from very low concentrations of plutonium containing materials is not economical.

R&D Activities

- **Immobilized Form Development**—Development work in this area focuses on providing: compositions of the ceramic immobilization forms that accommodate the range of plutonium feed materials expected; the related processing parameters for fabricating the plutonium forms; important physical and chemical properties of the final form needed for process/equipment development; and a preliminary product control model that establishes acceptable ranges for feed compositions and processing parameters. These development activities involve laboratory experiments with plutonium, uranium, desired neutron absorber elements, and the other materials contained

in the expected feed; non-radioactive experiments with surrogate materials; and analysis of data related to the feed material and the physical chemistry of the ceramic form.

- **Immobilization Process/Equipment Development**—Development work in this area involves: converting a wide range of feed materials into a homogeneous oxide feed to the immobilization process using mechanical and chemical process; blending this feed with uranium oxide and other ingredients; pressing the feed blend into disks; firing/sintering them into the immobilized plutonium ceramic form disks; and packaging cans of plutonium ceramic disks into arrays inside large canisters, which are then filled with molten high-level radioactive waste glass. Key process steps and equipment that need to be developed and tested for the specific ceramic formulation with actual plutonium feed materials include design of the canister package and internals, glass pour testing of prototype canisters, canister loading, and use of surrogate test materials.

- **Russian Process Development**—Work involves tests on the immobilization of plutonium in glass and ceramics and tests on the recovery of plutonium from glasses and ceramics.

Accomplishments

- Established baseline ceramic form that accommodates the expected range of impurities.

- Full-scale plutonium conversion test equipment was procured and assembled to support integrated testing this year. Prototype ceramification test equipment was procured and is nearing final assembly, for subsequent integrated testing this year.

- Tests confirmed the overall feasibility and practicality of the "can-in-canister" technology. Three pours of simulated high-level waste glass into actual canisters containing cans of simulated ceramic disks showed that glass would fill all the spaces around the cans with no detrimental effect on their support structure.

- Performed small-scale tests of plutonium vitrification in Russia.

Reactor Option

Budget: FY99-$9.4M, FY00-$6.4M, FY01-$8.1M

Description and Objectives. The MOX technology is used in Europe and does not require extensive research and development for implementation in the U.S. The effort is directed at fabricating samples of MOX fuel and conducting limited experiments and tests of the sample MOX fuel to assess the effect of gallium contained in weapons-grade plutonium on fuel performance. The objective of this effort is to assure the plutonium and uranium material forms used for fabricating MOX fuel will produce acceptable fuel, and examine key issues related to the successful performance of MOX fuel in commercial nuclear reactors.

R&D Challenges. The challenge is understanding and reconciling the differences between MOX fuel produced from weapons-derived plutonium and that which is commercially produced in Europe. Differences include variation in plutonium oxides, isotopics, and the presence of impurities introduced in the manufacturing of nuclear weapons, i.e., pits. In addition, the MOX fuel containing small amounts of gallium may need to be shown to be acceptable for commercial power plant use.

R&D Activities

- **MOX Fuel Qualification**—Activities involve irradiating sample fuel made from weapons origin plutonium and completing post-irradiation examination to determine fuel performance.

Accomplishments

- Established preliminary process parameters for MOX fuel fabrication using powder derived from weapons plutonium metal conversion.
- Developed bench-scale analytical method for detecting gallium in Pu oxide powder/fuel and completed basic R&D on gallium/fuel cladding interactions.
- Developed draft plutonium oxide feed specification.
- Fabricated, irradiated, and began examination of demonstration MOX fuel.

Nuclear Materials Protection

Budget: FY99-$21.3M, FY00-$25.2M, FY01-$25.0M

Background

In recent years, the worldwide proliferation of weapons of mass destruction has emerged as one of the most serious dangers confronting the United States. This is a continuing and evolving problem with far-reaching consequences for international and domestic security and stability. In response to this emerging threat to our security, the President directed the prioritization of a number of initiatives and programs throughout the United States government and the Department of Energy. One of these priorities is the effective protection, control, and accountability of nuclear materials, technology, and expertise in the United States.

The Department of Energy has more nuclear materials on hand than at any time in history, and has an associated responsibility to protect these materials. Should a terrorist gain access to special nuclear materials (SNM) there is considerable potential for radiological sabotage which could endanger not only Department of Energy employees but also the general public. This scenario must be protected against. Other assets of national security significance requiring protection include nuclear weapons, weapons design information, and the national energy infrastructure.

Maintaining a technological "edge" over potential adversaries is an essential part of the DOE protection strategy, and since terrorists are becoming increasingly sophisticated and well funded, continued investments in protection technologies are required. Not only must the Department protect against the use of traditional terrorist tools such as bombs, explosives, and armed teams, but also insiders, lethal agents, directed energy weapons, and the terrorist use of computers.

For over 30 years the Department has invested in the development of safeguards and security measures and technologies at almost every national laboratory to help counter these threats and ensure the preservation of national security and public safety. It does not appear that investments in this area can be relaxed without accepting considerable risk to Departmental assets requiring protection, or the general public.

Program Description

The nuclear materials protection activity is focused on the following three areas:

- Nuclear Material Control and Accounting.
- Physical Protection.
- Information Security.

Technologies emerging from all of these areas are used by DOE facilities to offset specific threats. In order to make sure that projects funded under this program reflect capabilities that are truly needed, the program is formulated based on user needs that have been submitted by field sites. These needs are then expanded into requirement documents that can be used by laboratories and quality panels to provide input and oversight of projects that receive funding. Technologies often make their way to field users initially as part of a beta test program so that laboratory developers can receive direct feedback on the adequacy of their designs. Continuous dialogue with field users throughout the development cycle has lead to the successful fielding of numerous technologies and an improved security posture for the Department.

Materials Control and Accountability

Budget: FY99-$6.8M, FY00-$7.9M, FY01-$8.8M

Description and Objectives. Nuclear Materials Control and Accountability (NMC&A or MC&A) is that part of safeguards that detects or deters theft or diversion of nuclear materials and provides assurance that all nuclear materials are accounted for appropriately.

Materials accounting establishes and tracks nuclear material inventories and detects loss or diversion of nuclear materials. A materials accounting program employs physical inventories, measurements, accounting records, and reports to ensure that inventory records are correct and complete. It provides credible assurance that diversion has not occurred and that other functions of the safeguards system have been effective in protecting these materials.

Materials control limits access to nuclear materials to authorized personnel in authorized locations, ensures the integrity of accounting systems, and deters theft or diversion of materials.

Our objective is to develop technologies, technical expertise, and information that supports DOE field sites in their efforts to design, implement, and manage nuclear material control and accounting systems that meet the policy requirements of the Department.

R&D Challenges. Maintaining control and accountability of nuclear materials within the defense nuclear complex requires:

- Measurement technologies that can accurately quantify alternative nuclear materials to prevent the proliferation of these materials for use in the creation of weapons of mass destruction.

- Advanced methods for detecting shielded nuclear materials and for identifying specific materials (versus simple recognition of radiological material presence).

- Automated and unattended verification of vaulted inventories (in storage) to enhance worker safety, while simultaneously protecting those materials by reducing physical access.

- Self calibrating measurement equipment and non-nuclear standards to reduce exposure of employees to nuclear materials.

- Measurement capabilities that can measure the amount of special nuclear material in spent fuel assemblies which is not sensitive to geometry or configuration.

R&D Activities. DOE's approach involves:

- Application of advanced technologies to address the shortcomings between user needs and available solutions including:
  - Advanced calorimetry technologies for enriched uranium.
  - Detection technologies for shielded and mixed matrix materials.
  - Non-destructive assay systems for difficult-to-measure materials.
  - Calibration and standards technologies.
  - Spectrum analysis software for nuclear materials measurements.
  - Unattended vault surveillance.
  - Standardized materials accounting database.

- Maintenance of core competencies in nuclear materials detection, measurement, control and accountability.

- Provision of DOE site support for nuclear materials measurement and control issues.

Accomplishments. Recent accomplishments include:

- Fielded a radionuclide identification system.
- Developed advanced technologies to prevent the theft or diversion of special nuclear materials, including the unattended, on-line gamma-ray monitor.
- Developed a portable measurement tool for gross nuclear material mass determinations.
- Provide matrix correction techniques that provide accurate measurement of large crates to prevent smuggling of special nuclear materials.
- Provide a low-wattage electrical calibration heater system to calibrate calorimetry instruments.
- Developed nondestructive assay standards.
- Developed sensors for detection of SNM and other property for use at vehicle and pedestrian portals to prevent theft or diversion of special nuclear materials.
- Developed an electro mechanically cooled HPGe gamma-ray detector to replace liquid nitrogen cooled systems when liquid nitrogen is not practical.
- Developed a Pu isotopic analysis capability for use with room-temperature CdZnTe detector systems.
- Developed a Compton suppression system based upon digital signal processing techniques. This system will significantly reduce the time it takes to make nuclear materials accountability measurements and thus reduce personnel radiation exposures as well as the time nuclear material sources have to be handled.
- Provided a cost-effective technique for rapid nondestructive assay of plutonium in residues and impure materials.
- Completed software for calorimetry measurements of fissile materials in DOE facilities.
- Provided a new instrument to measure uranium that is less time intensive and more cost effective.

Physical Protection

Budget: FY99-$10.3M, FY00-$11.4M, FY01-$13.8M

Description and Objectives. DOE develops technologies, technical expertise, and information that supports DOE field sites in their efforts to design, implement, and manage protection systems that meet the policy requirements of the Department and mitigate the official DOE design basis threat.

Protecting the people and physical assets present throughout the national defense nuclear facilities requires continuous measurement of the vulnerabilities and performance characteristics of deployed and emerging protection systems. Specific threats that must be countered by protection, detection, and mitigation technologies include protection against terrorist attacks, the activities of malicious "insiders", and the adversary use of explosive, chemical, or biological agents. Additionally, protective forces within nuclear facilities face a number of unique operational constraints (for example, nuclear process equipment must not be struck by a ricocheting bullet).

R&D Challenges. Achieving physical protection objectives requires overcoming a number of challenges:

- To enable design and management of effective security systems, good security system modeling and vulnerability analysis techniques must be available. Good modeling systems rely on accurate security system performance information originating from solid testing programs. Current resources do not permit adequate performance information to be generated.

- Recent tests have shown that barriers and vault systems used by the Department are not as robust as once thought. An activated barrier that supplements existing physical barriers is therefore required.

- Balancing the above requirements against planned developmental improvements in critical existing security systems such that they do not become obsolete.

- Development of technologies to address known vulnerabilities within current budget constraints.

R&D Activities. The Physical Protection program invests in the following seven areas:

- Quantification of the performance of security equipment against current and emerging threats:
  - Interior and exterior sensors.
  - Explosives detection equipment.
  - Access delay equipment.
  - Video equipment.
  - Entry control and biometrics.
  - Vehicle and personnel screening.

- Elimination of specific protection system vulnerabilities and deficiencies.
- Explosive detection and protection.
- Protective system modeling and analysis.
- Alarm annunciation and access control improvement (ARGUS).
- Protective force equipment improvement.

Accomplishments. Technological means have been applied to develop, modify, test, or implement numerous physical protection, detection, assessment, delay and response capabilities throughout the DOE complex:

- Redesign of an activated barrier currently in use throughout the DOE complex to extend operational shelf life and confidence.
- Fielding of frangible non-lead ammunition.
- Fielding of an automated closed-circuit television (CCTV) camera tester.
- Fielding of a relocatable security system.
- Fielding of a high security wireless alarm communications link.
- Fielding of a technology capable of screening vehicles for hidden people.
- An advanced operator training simulation tool for high-security dispatch application where the protection of critical national assets and national security are at stake.
- Modernize the Department's standardized alarm and access control system (ARGUS) to prevent unauthorized access to DOE facilities and assets. Efforts include replacing outdated software, re-engineering the database and user interface, and adding neuron chip based smart sensors.
- Provide a wind-suppression algorithm for the human presence detection system which detects unauthorized humans hidden within a vehicle.
- Develop a high energy compact cartridge which can be inserted into a shotgun to provide for the selection of a less than lethal to a lethal response to intruders.
- Provide recommendations to DOE sites on the use of high-intensity acoustics for access delay applications.

Information Security

Budget: FY99-$4.2M, FY00-$5.9M, FY01-$2.4M

Description and Objectives. The facet of national security that involves protecting information and information systems that exist within the defense nuclear complex continues to expand in scope and complexity. Weapons design data must be carefully protected (confidentiality); the integrity of various forms of research data must be assured (integrity); and many systems that affect worker and public safety must not be disrupted (availability). Detection of unauthorized cyber activity, that may be distributed over time or geographical location, remains a true challenge for the technical and operational communities. The capability to respond to cyber attacks and to reconstitute affected systems requires tools and methods that provide understanding of how systems act and react under widely varying conditions.

R&D Challenges. As mentioned in the report by the President's Commission on Critical Infrastructure Protection:

> "A satchel of dynamite or a truckload of fertilizer and diesel fuel have been frequent terrorist tools. The explosion and the damage are so certain to draw attention that these kinds of attacks continue to be among the probable threats to our infrastructures. Today, the right command sent over a network to a power generating station's control computer could be just as effective as a backpack full of explosives, and the perpetrator would be harder to identify and apprehend.
>
> The rapid growth of a computer-literate population ensures that increasing millions of people possess the skills necessary to consider such an attack. The wide adoption of public protocols for system interconnection and the availability of "hacker tool" libraries make their task easier.
>
> While the resources needed to conduct a physical attack have not changed much recently, the resources necessary to conduct a cyber attack are now commonplace. A personal computer and a simple telephone connection to an Internet Service Provider anywhere in the world are enough to cause a great deal of harm.
>
> Of the many people with the necessary skills and resources, some may have the motivation to cause substantial disruption in services or destruction of the equipment used to provide the service."

The DOE cyber security program faces many dynamic and complex challenges involving critical government functions that impact national security. These challenges include:

- The detection of unauthorized cyber activity that may be distributed over time or geographical location is important.
- The interconnectivity of computer systems makes it increasingly important to prevent and detect unauthorized access to computer systems due to many vital processes and systems being threatened by one unauthorized individual.

- The proper technologies must also be in place to prevent an authorized insider from adverse activities.

- The dynamics of the computer industry cause currently available tools for detecting adversary action to become quickly outdated, and thus there is a constant requirement to remain on the cutting edge.

- The capability to immediately respond to cyber attacks and to reconstitute affected systems is essential.

R&D Activities. DOE activities are directed towards:

- Developing an automated protection system that will detect anomalous activities on a computer network and automatically respond to mitigate any potential damages.

- Developing advanced tools and technologies to detect/prevent penetrations to computer networks.

- Providing an automated low-cost, experience-based, training capability for network system administrators.

- Providing technical assistance on current threats to DOE information networks.

- Determining attack mitigation strategies.

Accomplishments. In no other area do technology-based vulnerabilities and solutions "leap-frog" each other as rapidly as in the world of information technology. Examples of DOE accomplishments fall in the following areas:

- Automated security profiling tools to assess general system security capabilities.

- Network intrusion detection tools.

- Computer Incident Advisory Capability (CIAC) services.

Several tools and documents have been created as part of funded DOE projects. These tools tend to be finished products, developed for a particular information system/network or, alternatively, for the DOE at large. Programs such as SPI-Net (Security Profile Inspector for Networks), SSDS (Secure Software Distribution System), and NID (Network Intrusion Detector) fit in the later category. Not all of these tools are available to the general public for obvious reasons.

The Security Profile Inspector for Networks (SPI-Net) software product provides a suite of security inspections for most Unix systems at the touch of a button. This security inspection suite includes Quick System Profile, Access Control Test, Binary Authentication Tool, Password

Security Inspector, Change Detector Tool, and Promiscuous Mode Checker. The Security Profile Inspector is a vulnerability and intrusion detection tool for both Microsoft Windows NT and UNIX systems. Among its features, it inspects for binary file modifications, vulnerable system versions, weak passwords, vulnerabilities from security misconfigurations, and changes on files and directories, thereby protecting from inadvertent user modification as well as intrusions and viruses. The Security Profile Inspector is freely available to all U.S. Government agencies and to contractors directly supporting the U.S. Departments of Energy and Defense.

The Secure Software Distribution System (SSDS) provides automated analysis of network-based computer systems to determine the status of security patches. SSDS determines what patches need to be installed. For the patches that are installed, SSDS checks the permissions and ownership of the files referenced in the patch and ensures that the system software is authentic. SSDS is composed of two components: a Patch Server and a Vendor Server. Currently, SSDS detects patch deficiencies on Sun systems that run Solaris 2.3 or newer. SSDS is freely available to all U.S. Government agencies, and to contractors directly supporting the U.S. Departments of Energy and Defense.

The Network Intrusion Detector (NID) software product provides a suite of security tools that detects and analyzes network intrusions. NID provides detection and analysis of intrusions from individuals not authorized to use a particular computer, and from individuals allowed to use a particular computer, but who perform either unauthorized activities or activities of a suspicious nature on it. NID is available for use by all authorized Department of Energy offices, national laboratories and facilities; Department of Energy contractors who directly support DOE; and U.S. Government civilian federal agencies.

The Workstation Daylock is a combination of software and a hardware alarm card for protecting a PC workstation from access by unauthorized personnel.

The DOE Information Security Server (DOE-IS) is an advanced server on the Internet whose goal is to enhance information security data sharing within the United States Department of Energy (DOE) community. The DOE community includes all DOE sites and contractors. The Server contains tools and documents related to information security that have been made available by many sources both within and outside of the DOE.

The Computer Incident Advisory Capability (CIAC) group assists the Department of Energy in its information protection efforts by providing computer security incident response related services. CIAC provides on-call technical assistance and information to Department of Energy (DOE) sites faced with computer security incidents. This central incident handling capability is one component of all-encompassing service provided to the DOE community by CIAC. The other services CIAC provides are: awareness, training and education; trend, threat, and vulnerability data collection and analysis; and technology watch.

Proliferation Resistant Fuel Cycle Technologies

Budget: FY99-$3.8M, FY00-$4.3M, FY01-$24.3M

Background

Reducing the threat of the proliferation of nuclear weapons continues to be one of the foremost goals of United States foreign policy. A key element of this policy is the reduction, and eventual elimination, of highly enriched uranium (HEU) in civil commerce. HEU is used as fuel for nuclear research and test reactors and as targets for medical isotope production, but can also be used in nuclear weapons.

Since the 1950s the United States has provided peaceful nuclear technology to foreign nations in exchange for their promises not to develop nuclear weapons. A major part of this program has been to provide research reactor technology to allow recipient nations to pursue medical, agricultural, and industrial applications of nuclear energy.

To reduce the danger of nuclear weapons proliferation, the United States in 1978 began the Reduced Enrichment for Research and Test Reactors (RERTR) program. One of RERTR's most important and successful activities has been the development of low enriched uranium (LEU) fuels to permit conversion of research reactors from HEU.

Both the U.S. and Russia have interests in and responsibilities for reducing the risk of nuclear proliferation from civilian nuclear power, and both are pursuing technology development programs to accomplish that goal. Continuing interactions with Russian officials on this topic will lead to the identification of many areas where the U.S. and Russian philosophies and technologies contributing to the development of proliferation-resistant nuclear systems will overlap. Successful collaboration between the United States and Russia will identify areas of mutual interest. The Department of Energy intends to accelerate development of proliferation-resistant nuclear systems by implementing a new research initiative (the Proliferation Resistant Reactors and Fuels Research Program) during FY 2001.

Program Description

The fundamental objective of the RERTR program is to provide the technical means needed to minimize, and eventually eliminate, international traffic in highly enriched uranium (HEU) for civilian purposes, and thereby to reduce the nuclear weapons proliferation potential of such material. To achieve this goal, the RERTR program develops the technical means needed to fabricate and qualify low enriched (less than 20% fissionable U^{235}, remainder non-fissile U^{238}) fuel and other research reactor devices such as targets for producing molybdenum-99, and to develop and test new targets and modified chemical processes to produce molybdenum-99. Currently, these fuels and targets are fabricated and qualified using highly enriched uranium (90 to 93% fissionable U^{235} and less than 10% U^{238}).

The Proliferation Resistant Reactors and Fuels Research Program is a collaborative research and development effort with Russia. The initial objective of the program is to develop proliferation resistant requirements and design modifications to existing Russian systems and develop new concepts for next-generation proliferation resistant reactor systems with improved safety. Following a review and assessment of existing, operating reactors in Russia, research will focus on development of reactor modifications for improvement of proliferation resistance and development of a plan leading to a new nuclear power system design to achieve the proliferation resistance objectives.

R&D Challenges. The major obstacle to converting the most sophisticated high-power research reactors is the lack of fuel with adequate density. In the past, HEU was used in order to provide enough fissile uranium within the density achievable for these fuels and other devices. In order to convert the reactor to LEU fuel, while still providing enough fissile uranium, more non-fissile uranium must be incorporated into the fuel matrix, resulting in a denser fuel. The current effort, which began in March 1996, is focused on developing fuels with a uranium density in the range of 8 to 9 grams of uranium per cubic centimeter of fuel. While progress has been made, the best density achieved thus far has been around 4 to 5 grams of uranium per cubic centimeter.

The eventual success of the Proliferation Resistant Reactors and Fuels Research Program and the pace of successful implementation will be dependent upon the quality of interactions and cooperation with Russian officials. Recent program collaboration discussions have been very encouraging

R&D Activities.

RERTR Program research and development activities are focused on two activities:

- Fuel Development to:
  - Develop fabrication techniques for research and test reactor fuels of very-high-density, but low-enrichment, uranium for use in the more powerful and sophisticated research reactors unable to use current technology LEU fuels.
  - Perform the tests needed to qualify the new LEU fuels.
  - Demonstrate the same performance with the new LEU fuels as achieved with current HEU fuels.

- Target Development to provide alternative targets and chemical processes which will allow the use of LEU to produce fission-product molybdenum-99 for use in medical applications including:
  - Development of target fabrication technology.
  - Development of chemical process technology for recovery and purification of the molybdenum-99.
  - Adaptation or development of technology for disposing of radioactive waste.
  - Obtaining FDA approval to market the drug product produced using LEU instead of HEU.

Proliferation Resistant Reactors and Fuels Research Program research and development activities are focused on two activities:

- Near-term technologies that might be developed and implemented such as
  - increasing the burnup of current fuel systems.
  - additives to the fuel to make reprocessing difficult.

- Longer-term technologies that require substantial research and development activity.

Many ideas have been proposed, both in the United States and Russia, to improve the proliferation resistance of existing nuclear systems as well as those being constructed or designed now. Many of these ideas will require substantial research and development to realize and it is likely that this research and development will take several years.

A number of alternative light water reactor fuel and fuel cycles, as well as enhancements to existing fuel cycles, have been proposed which can increase the proliferation resistance of both current and new (yet not constructed) reactors. Those destined for new systems may have a higher potential for success because those plants have not been constructed and hence costly modifications, and/or component replacement is not required. Some ideas suggested include:

- New Fuel and Fuel Cycle - High burnup, long cycle length cores (36 month or more cycle time), possible use of Th/U, or other fuel technologies. Advantage: increase the time between refueling, less fuel handling, very difficult to remove fissile material because of high gamma radiation levels.

- Advanced Proliferation-Resistant Fuel - elimination of fertile material in fuel, e.g. elimination/replacement of U^{238} with an equivalent Doppler absorber, hence no generation of Pu^{239}.

Meeting the new and increasingly difficult challenges facing nuclear power will likely require development of nuclear power systems radically different than those now in use or even those considered in the past. Given this opportunity to rethink the design requirements, including the fuel and fuel cycle, opens the door to the next generation of reactors that are being referred to as "Generation IV" nuclear power systems. The motivation of Generation IV is to provide the technologies necessary to achieve the goals of competitive economics, improved safety, improved environmental benefits and enhanced proliferation resistance. Generation IV systems and technologies will also be based on meeting the particular needs of potential clients, including, for example, reducing the need for a complex "in country" nuclear technology infrastructure of systems designed for the developing world. Generation IV technology is defined as revolutionary, and not necessarily limited to extrapolation of today's technologies.

Next-generation fuel cycle technologies must consider, as an integral part of their designs, the complete fuel cycle including the waste stream and proliferation risks. At least one concept has been proposed that avoids the generation of additional fissile material, most notably Pu^{239}. This technology is referred to as "non-fertile fuel" (NFF). Limited research for civilian application

has taken place, however, the interest in this area has expanded recently as part of the DOE Fissile Materials Disposition activity related to the Russian plutonium disposition program.

There are various options for reducing the vulnerabilities at the back-end of the fuel cycle. Some, such as reprocessing schemes that avoid complete separation of plutonium, could reduce the proliferation risks associated with closed fuel cycles sufficiently to resolve many of the policy objections to the closed fuel cycle. Others have been proposed to burn the actinides (again mostly Pu) found in spent fuel using either reactors or accelerator-driven sub-critical assemblies. These approaches could reduce the long-term proliferation risks associated with both spent fuel storage and geologic disposition of spent fuel.

Accomplishments

- Approximately two-thirds of the work required to eliminate use of HEU in U.S.-supplied research reactors has been accomplished. The program's development of a low enriched fuel makes it possible for all but six western reactors (with power greater than one megawatt) to convert. Of the U.S.-supplied reactors with power greater than one megawatt that are able to convert, most have planned to do so.

- The RERTR program has supported reactor conversion efforts in two dozen countries and supports the Foreign Research Reactor Spent Fuel Acceptance Policy, involving over forty countries.

- Recent irraditation tests of a low enriched uranium-molybdenum alloy fuel sample have shown excellent results, exceeding the potential of uranium-silicide alloy fuel.

- A prototype LEU target for medical isotope production has been developed and is being tested in Indonesia. The RERTR program is conducting joint development work on LEU targets for medical isotope production with Indonesia, Argentina, Canada, and South Korea and is beginning joint work with Australia.

Summary Budget Table (000$)

Research Areas	FY 1999 Appropriated	FY 2000 Appropriated	FY 2001 Request
Fissile Material Disposition	**43,800**	**45,600**	**45,100**
Pit Disassembly and Conversion	17,900	17,400	15,400
Immobilization	16,500	21,800	21,600
Reactor Option	9,400	6,400	8,100
Nuclear Materials Protection	**21,300**	**25,200**	**25,000**
Materials Control and Accountability	6,800	7,900	8,800
Physical Protection	10,300	11,400	13,800
Information Security	4,200	5,900	2,400
Proliferation Resistant Fuel Cycle Technologies	**3,800**	**4,300**	**24,300**
Total	**68,900**	**75,100**	**94,400**