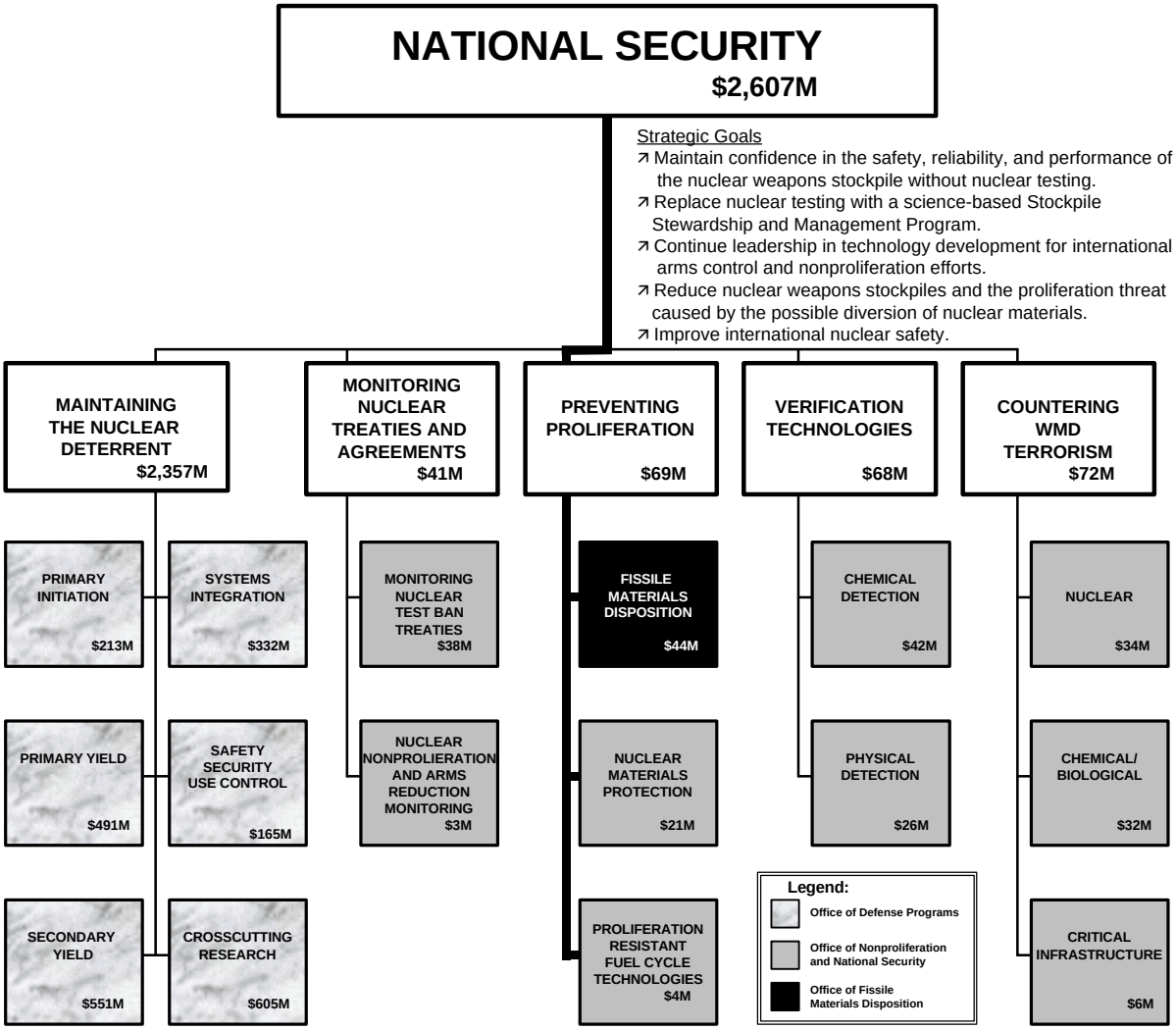
Chapter 5
Preventing Proliferation



Chapter 5
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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.

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 and
- Presidential Summit Agreement Moscow 1996 and Helsinki 1997 (that is, excess fissile materials storage and disposition transparency).

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 1999. 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.

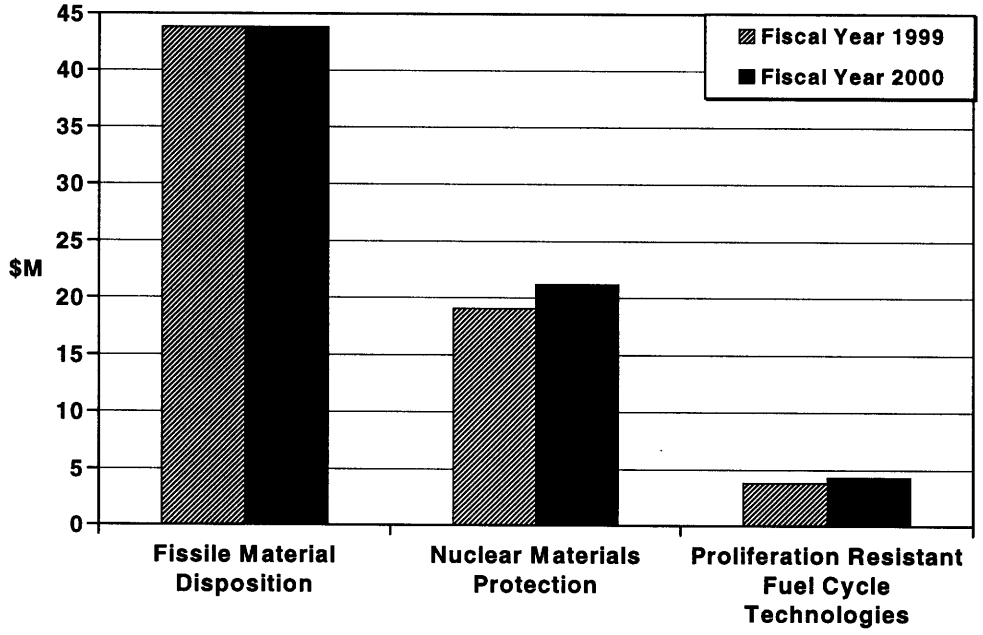
Investment Trends and Rationale

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 FY2002 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 FY2000. 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 chart shown below shows investments by activity areas that will be discussed in the remainder of this chapter.

Preventing Proliferation



Federal Role

Congress in Public Law 103-337 directed that DOE establish an Office of Fissile Materials Disposition and that the head of the Office shall be responsible for all activities of the Department relating to the management, storage, and disposition of fissile materials from weapons and weapons systems that are excess to the national security needs of the United States.

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. Eight of 30 different pit designs have been disassembled and converted. In Russia, the development of a Russian plutonium conversion and nondestructive assay prototype was initiated. In immobilization, the baseline ceramic form was established and detailed flowsheets and equipment concepts were prepared. 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 a pyrochemical process of weapons plutonium metal conversion, were established. Sample MOX fuel from this process was fabricated, irradiated, and examined. Also, analytical methods for detecting gallium and basic research and development on gallium/fuel cladding interactions were completed.

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: FY98-$44.7M, FY99-$43.8M, FY00-$43.8M

Background

The Department, in a Record of Decision on the Fissile Materials Storage and Disposition Programmatic Environmental Impact Statement issued January 1997, announced a strategy 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 needs to resolve issues associated with potential impacts to fuel performance from other materials alloyed in plutonium in order to have confidence that this approach can also provide success in a timely and cost-effective manner.

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: FY98-$19.4M, FY99-$17.9M, FY00-$18.3M

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 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 will be manually demonstrated on about 50 pits. Then the canning system will be automated and the automated canning and NDA system will be demonstrated on about 200 pits, 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 and beryllium hemishells.

- **Development of Robotics**—Several of the process steps will be automated to reduce the radiation exposure to operators. Requirements for robotics will be developed and robots selected and 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

- Designed, constructed, and started a full scale demonstration system of core functions at Los Alamos National Laboratory.

- Designed, constructed, and started operation of full-scale glove box modules for pit bisection and plutonium oxidation at Lawrence Livermore National Laboratory.

- Disassembled and converted plutonium from eight of 30 different types of surplus pits.

- Demonstrated a fully automated NDA system.

- Initiated development of a Russian plutonium conversion and nondestructive assay prototype system.

Immobilization

Budget: FY98-$14.7M, FY99-$16.5M, FY00-$18.0M

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.

- Defined detailed flowsheets and equipment concepts. Completed feasibility demonstrations for several key processes. Key prototype equipment is being procured and assembled. A ceramification test system has been designed and is being

assembled. Concepts for disk handling and can loading have been successful in feasibility tests. A simplified system for loading cans into canisters was successfully demonstrated.

- Conceptual design of the can-in-canister configuration was completed.

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

Reactor Option

Budget: FY98-$10.6M, FY99-$9.4M, FY00-$7.5M

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

- **Evaluate Effects of Variations in Fuel Oxides**—Activities involve producing plutonium and uranium oxide powder that is different from that produced in the European process and fabricating MOX fuel to demonstrate the suitability of these different feed materials.

- **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 a pyrochemical process of 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 that was produced using a pyrochemical process.

Nuclear Materials Protection

Budget: FY98-$17.7M, FY99-$19.1M, FY00-$21.2M

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 two areas:

- Nuclear Material Control and Accounting.
- Physical Protection.

Technologies emerging from both 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: FY98-$10.3M, FY99-$9.8M, FY00-$10.1M

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 nuclear materials embodied in “mixed matrix” form.
- 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.

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 small samples and in-process glove boxes
  - Detection technologies for shielded and mixed matrix materials
  - Non-destructive assay systems for difficult-to-measure materials
  - Interfaces linking measurement systems to accounting databases
  - Calibration and standards technologies
  - Spectrum analysis software for nuclear materials measurements

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

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

Accomplishments. Recent accomplishments include:

- Development and fielding of non-destructive assay systems for characterization of SNM in packages and waste drums,

- Advancements in vehicle and personnel portal SNM detectors,

- New calorimeter operating systems capable of integrating multiple calorimeters simultaneously, and

- Fielding of autonomous vault inventory monitoring systems to detect unauthorized tampering with or removal of SNM.

Physical Protection

Budget: FY98-$7.4M, FY99-$9.3M, FY00-$11.1M

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 the activities of malicious "insiders", and the

presence of explosive, chemical, or biological agents. Additionally, protective forces within nuclear facilities face a number of unique operational constraints (for example, nuclear reactors 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 system modeling and 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 barriers is therefore required. Although many approaches have been investigated, a promising technological alternative has not yet been identified.

- Development of intrusion detection equipment that can be used to replace existing equipment before it is discontinued by commercial manufacturers.

- Balancing the above requirements against planned developmental improvements in critical existing systems (like ARGUS and ASSESS) such that they do not become obsolete.

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 protection.

- Protective system modeling and analysis.

- Alarm annunciation and access control improvement (ARGUS).

- Protective force performance 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 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.

Proliferation Resistant Fuel Cycle Technologies

Budget: FY98-$3.5M, FY99-$3.8M, FY00-$4.3M

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.

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}).

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.

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.

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 1998 Appropriated	FY 1999 Appropriated	FY 2000 Request
Fissile Material Disposition	**44,700**	**43,800**	**43,800**
Pit Disassembly and Conversion	19,400	17,900	18,300
Immobilization	14,700	16,500	18,000
Reactor Option	10,600	9,400	7,500
Nuclear Materials Protection	**17,700**	**19,100**	**21,200**
Materials Control and Accountability	10,300	9,800	10,100
Physical Protection	7,400	9,300	11,100
Proliferation Resistant Fuel Cycle Technologies	**3,500**	**3,800**	**4,300**
Total	**65,900**	**66,700**	**69,300**