**Overview
of the
Defense Programs
Research and Technology
Development Program
for
Fiscal Year 1993**

September 30, 1993

**US Department of Energy
Assistant Secretary for Defense Programs
Deputy Assistant Secretary for Military Application
Office of Research and Advanced Technology
Research and Technology Development Division
Washington, DC 20585**

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**DEFENSE PROGRAMS
RESEARCH and TECHNOLOGY DEVELOPMENT**

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RESEARCH and TECHNOLOGY DEVELOPMENT

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**DEFENSE PROGRAMS
RESEARCH and TECHNOLOGY DEVELOPMENT**

Forward

In August of 1991, RADM W. G. Ellis, in his capacity as Deputy Assistant Secretary for Military Application, requested that Los Alamos National Laboratory, Lawrence Livermore National Laboratory, and Sandia National Laboratories participate in nine interlaboratory planning groups for the purpose of developing individual Program Element Plans addressing each of the nine core science and technology competencies that are managed by the Research and Technology Development (R&TD) Division as elements of the overall **Research and Technology Development Program**. The resulting **R&TD Program Element Plans**, completed by the Laboratories in the Spring of 1992, documented the ongoing and planned activities, as well as the anticipated milestones, in each of these nine technology areas. This planning process, which addressed Fiscal Years 1992 through 1997, made an important contribution to interlaboratory communication and coordination. More importantly, however, it was a significant first step toward restructuring the traditional "technology base" portion of the Weapons Activities Research, Development, and Testing Program, specifically that portion within budget category GB010301. The nine **R&TD Program Elements** now form the structure for this budget category, for the sections addressing the R&TD Program within the Defense Programs MultiYear Program Plan (DPMYPP), and for discussions of Research and Advanced Technology in the President's Budget Submission to Congress. This document summarizes the current **R&TD Program Element Plans** and provides an overview of the nature and importance of Departmental activities in these vital science and technology areas.

The new Administration and the new Congress are being challenged to address a number of critical issues, including questions regarding defense reconfiguration and conversion, deficit reduction, and economic competitiveness. In this context, a concrete understanding of existing programmatic activities and objectives will be crucial to effective decision-making, particularly because the R&TD Program has a crucial impact on all post-Cold War DOE Defense Programs Missions, on the DOE Defense Critical Technologies, and on national efforts in advanced manufacturing, advanced materials and processes, and high performance computing and communications. These "longer term, larger scale, high risk, high return" types of activities are comprehensively funded only within the R&TD Program; however, they contribute to a multitude of vital initiatives, both within the DOE and across the Nation. This document, including updates of planned activities and anticipated milestones, reflects budget and funding levels that were projected in April of 1993. As such, this document provides an essential point of departure for Fiscal Year 1994 and "outyear" Research and Advanced Technology planning.

The efforts of Michael Norte of Sandia National Laboratories, in integrating input from all three of the Defense Programs National Laboratories, is gratefully acknowledged.

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Preface

**Assistant Secretary
for
Defense Programs**

**Deputy Assistant Secretary
for
Military Application**

**Office of Research
and
Advanced Technology**

**Research and
Technology Development
Division**

The Research and Technology Development Division, as part of the Office of Research and Advanced Technology for United States Department of Energy Defense Programs, coordinates and ensures the maintenance and advancement of fundamental scientific and technical capabilities that are required to support the defense missions of the Department of Energy. This includes missions that fall outside the direct responsibilities of the Assistant Secretary for Defense Programs. The primary responsibility of the Division is programmatic oversight of research and enabling technology development activities that assure the surety, reliability, and military effectiveness of the nuclear weapons stockpile and the credibility of the deterrent. An additional responsibility, of increasing importance, is to promote domestic industrial competitiveness through the development of appropriate "dual use" technology. This document represents an overview of these responsibilities and of the approach and structure used by the Division in meeting them.

Conceptual
Design
and
Assessment

Physics

Computation
and
Modeling

System
Engineering
Science
and
Technology

Electronics,
Photonics,
Sensors, and
Mechanical
Components

Chemistry
and
Materials

Special
Nuclear
Materials

Tritium

Explosives

DEFENSE PROGRAMS
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Programmatic Overview

In the broadest terms, the mission of the Research and Technology Development Division is to maintain and enhance the Nation's ability to apply technological leverage toward national security objectives. The Nation's history has continually reflected the ability to develop and apply such technological leverage. As a Nation, the United States met the challenges of the Cold War by building and sustaining the sources of innovation within its own society, by fully applying the resulting technological leverage, and by maintaining constant vigilance against technological surprise.

The demise of the Soviet Union and the bipolar "balance of power" has created a new multipolar world. It has not, however, eliminated the basic forces that have driven history in the past. As regional aggressors continue to pursue the technologies of war, our world continues to be threatened by the spread of military technologies that range from improved conventional weaponry and enhanced delivery capabilities to chemical, biological, and nuclear weaponry. As relations between East and West improve, we are reminded that the road to complete stability will be long and that old arsenals will remain large for some time to come. With the end of the Cold War, our nuclear weapon stockpile is appropriately being reduced and the elements of the Former Soviet Union are being encouraged to pursue a stable future; however, although the strategic threat to our Nation has changed, the threat posed by the existence and proliferation of nuclear weapons technology remains. The primary mission of the Research and Technology Development Division continues to be one of providing the new scientific knowledge and the advanced technology

needed to support the rapidly changing set of DOE defense missions and activities.

While these concerns remain, new types of threats to U.S. security are rising. Many nations are now emulating the success of our economic system. The global stage has been set for an intense period of economic development and competition. Nations around the world are engaged in an unprecedented race to exert the leverage of technology toward the enhancement of their economies, their national interests, and the lives of their citizens. History has shown, however, that, under the influence of rapid growth and quick prosperity, the line between commerce and aggression can blur. In the past, the tensions between East and West dominated our national attention. Over the past twenty years, however, the United States has also been confronted by challenges ranging from foreign manipulation of our energy supplies to the erosion of our strategic industrial base, including our domestic sources of essential defense components. Today, our national security requirements extend beyond the basic need for military defense. As a Nation, we must mount an ever more comprehensive defense of all aspects of our national integrity. The competition between nations is now increasingly being decided by the ability of each nation to create and apply technological leverage to secure and sustain competitive advantage. In this context, the Department of Energy has been directed to assist with the enhancement of our national strategic industrial base through the development of "dual use" technology and its subsequent transfer to appropriate domestic industrial partners. This mandate forms the foundation for broader elements of the Division's mission.

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Thus, as a Nation, we face two broad challenges, both of which are driven by the constantly evolving nature of technology and the transient character of any form of technological advantage. First, in recognition of the continuing existence and spread of technologies of mass destruction, we are challenged to remain capable of countering any possible aggression and answering any threat of nuclear coercion. In this context, there continues to be clear agreement on the need to both maintain a credible nuclear deterrent and preserve the national capability and capacity to rebuild our forces in response to unforeseen circumstances. Second, in recognition of the impact of an increasingly competitive global economy, we are also challenged to ensure that our concepts of national interest and security remain current, realistic, and sufficiently comprehensive to encompass the full range of potential threats to our national integrity, including evolving national security concerns in the areas of national defense, energy security, economic security, and technical education.

Defense Programs Missions & Initiatives

To meet these evolving challenges, Defense Programs is pursuing, in accordance with the *Fiscal Year 1993 Defense Programs MultiYear Program Plan*, nine **Missions and Initiatives**, each addressing critical national security challenges of the Department of Energy. The research and technology development efforts associated with these **Missions and Initiatives** are vital in exercising and integral to maintaining essential core defense capabilities.

• Stockpile Stewardship

Stockpile Stewardship consists of basic and applied research, development, and testing activities that properly monitor, evaluate, and maintain the active stockpile; properly handle, store, and dismantle weapons and components being retired from the active stockpile; and support studies, design and engineering efforts, and technology demonstrations

associated with the development of replacement weapons and components. An area of immediate challenge is stockpile reduction. Areas of longterm interest include intrinsic and enhanced surety concepts, stockpile technology, stockpile improvement programs, and nuclear testing. Seven focal areas are currently associated with **Stockpile Stewardship**.

1. Stockpile Evaluation, Maintenance, and Support
2. Retirement, Dismantlement, and Storage
3. Studies, Engineering Development, and Technology Demonstration
4. Enhanced Surety
5. Stockpile Improvement Programs
6. Stockpile Technology
7. Weapon Component Testing

• Reconfiguration

Relevant elements of this **Initiative** include research and development in support of new and advanced production technologies and processes for integration into a smaller, modernized, weapon production and maintenance complex. In addition to capabilities in dismantlement and the disposition of nuclear materials, this reconfigured complex, scheduled to be in place early in the next century, will have modest capabilities for the manufacture or remanufacture of components for the enduring stockpile, will incorporate and demonstrate the most advanced feasible production technologies, will be fully compliant with applicable environmental safety and health requirements, and will operate with the highest efficiency consistent with the requirements in effect at the time. Nine focal areas are involved.

1. Strategic Planning and Analysis
2. Plutonium Technologies
3. Uranium Technologies
4. Lithium Technologies
5. High Explosives
6. Tritium Technologies
7. NonNuclear Components
8. System Assembly
9. Support Technologies

• Emergency Management & Response

Emergency Management and Response ensures that the capabilities necessary to respond to an incident or accident involving a nuclear

weapon or any other major incident or accident involving radiological materials, anywhere in the world, are maintained and properly utilized when needed. Research and study efforts, directed toward enhancing existing capabilities or developing new or additional capabilities, are also pursued through this Initiative.

1. Nuclear Emergency Search Team (NEST)
2. Federal Radiation Monitoring and Assessment Center (FRMAC)
3. Aerial Measuring System (AMS)
4. Atmospheric Release Advisory Capability (ARAC)
5. Accident Response Group (ARG)
6. Special Applications

• Special Projects, Education, and Partnerships

Special Projects and Partnerships encompass a wide range of relationships and activities that directly support the goals and objectives of the Defense Programs MultiYear Program Plan (DPMYPP). These activities currently fall into four areas.

1. Education Initiatives
2. Weapons Transportation Safeguards Systems
3. Extraordinary ES&H and General Site Remediation
4. Other

• Test Ban Readiness

Test Ban Readiness addresses the research and technology development needs resulting from both existing and potential constraints on testing, up to and including a complete ban on underground testing. These efforts are divided into three related focal areas.

1. Weapon Physics
2. Predictive Capability and Modeling
3. Weapon Component Effects Testing

• NonProliferation, Arms Control, and Threat Assessment

This Initiative, divided into five focal areas, consists of research and technology development in support of national policies on verification, arms control, and nonproliferation. It supports the

Office of Intelligence and National Security by providing an essential understanding of the full range of activities associated with the design, production, testing, and dismantlement of nuclear weapons and the production of Special Nuclear Materials (SNM). These efforts also address international assessments, detection of nuclear testing and chemical effluents, and development of disablement capabilities.

1. Policy Support
2. Assessments and Technology Surprise
3. Proliferation Response Technologies
4. Operational Support
5. Testing Infrastructure

• Inertial Confinement Fusion

These efforts pursue pure thermonuclear burn in the laboratory. Although their primary defense applications are in studies of weapon physics and weapon effects and for the simulation of weapon effects, they also contribute to the longterm development of fusion energy. Currently, the primary program thrust is toward ignition. Work is focused on the development of three candidate driver technologies and the evaluation of two different driver/target coupling schemes.

1. Indirect Drive with a Glass Laser Driver
2. Direct Drive with a Glass Laser Driver
3. KrF Laser Driver
4. Light Ion Beam Driver
5. Capsule Fabrication and Development

• Technology Transfer

The purpose of the **Technology Transfer Initiative** is to coordinate and support collaborative efforts, between Defense Programs and the domestic industrial sector, toward the development of "dual use" technologies in support of both DOE National Security Missions and the enhancement of national industrial and economic competitiveness. There are currently six technical focal areas within this Initiative.

1. Precision Engineering and Advanced Manufacturing
2. Materials and Processes
3. Microelectronics and Photonics
4. Computer Architectures and Applications
5. Energy and Environment
6. Biomedical Technologies

DEFENSE PROGRAMS RESEARCH AND TECHNOLOGY DEVELOPMENT

• Research and Technology Development

In meeting programmatic goals, each of the previously mentioned eight **Defense Programs Initiatives** conducts applied research and technology development activities that exercise, maintain, and advance the scientific and technological capabilities of the Department. The activities of these **Initiatives** are, however, managed to reach immediate programmatic goals and not to preserve core defense capabilities. Thus, although the immediate availability of basic scientific and technological capabilities is often critical to their success, these **Initiatives** are generally focused only on meeting their own programmatic needs and not on the development or maintenance of broad essential capabilities. For this reason, the *FY1993 Defense Programs MultiYear Program Plan* identified the development and maintenance of broad core capabilities as a primary **Mission**, essential to and interrelated with all eight of the **Defense Programs Initiatives**. The purpose of the Research and Technology Development Program is to maintain these core scientific and technological competencies.

The Research and Technology Development Division is charged with monitoring the research and technology development needs of Defense Programs as a whole and ensuring that the scientific and technical capabilities, the core defense competencies, to meet those needs remain continuously and reliably available. The necessary levels of capability in each area of technology are monitored, first, to assure that the needs of ongoing **Defense Programs Initiatives** are met and, second, to ensure that anticipated needs will

be properly met in the future. When the need for a specific capability overlaps multiple **Initiatives**, that capability can usually be most effectively managed as an element of a common technological infrastructure. The integrated management of such capabilities is achieved through their inclusion as an element of the Research and Technology Development Program. These capabilities are, by definition, multiprogrammatic in nature and each of them supports and enables multiple **Initiatives**.

To effectively maintain these essential and multiprogrammatic technological capabilities, the Research and Technology Development Program is subdivided into nine broad technology areas. These disciplinary areas are known as the **R&TD Program Elements**. The nine **R&TD Program Elements** are further grouped into three technical clusters.

1. Design Sciences and Advanced Computation
 - a. Conceptual Design and Assessment
 - b. Physics
 - c. Computation and Modeling
2. Advanced Manufacturing Technologies & Capabilities
 - d. System Engineering Science and Technology
 - e. Electronics, Photonics, Sensors, & Mechanical Components
3. Advanced Materials Sciences and Technologies
 - f. Chemistry & Materials
 - g. Special Nuclear Materials
 - h. Tritium
 - i. Explosives

Figure 1 illustrates the important programmatic relationships between the nine **R&TD Program Elements** and the current **Defense Programs Missions and Initiatives**.

Legend to Figure 1:

CRITICAL IMPORTANCE.....the R&TD Program Element provides essential capabilities

IMPORTANT RELATIONSHIP.....the R&TD Program Element provides significant benefit to the initiative

DIRECT OVERLAP.....the R&TD Program Element is contained within the technology cluster

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Figure 1:
Programmatic Relationships

Figure 1: Programmatic Relationships		the R&TD Program Elements									
		Design & Assessment	Physics	Computation & Modeling	System Engineering	Components	Chemistry & Materials	Special Nuclear Materials	Tritium	Explosives	
Department of Energy Defense Activities	Stockpile Stewardship	Stockpile Evaluation, Maintenance, and Support	○	○	●	●	●	●	○	○	●
		Retirement, Dismantlement, and Storage	○	○	●	●	●	●	○	○	○
		Studies, Engineering Development, & Tech Demonstration	●	●	●	●	●	○	○	○	○
		Enhanced Surety	●	○	●	●	●	○	○	○	○
		Stockpile Improvement Program	●	●	●	●	●	○	○	○	○
		Stockpile Technology	●	●	●	●	●	○	○	○	○
	Reconfiguration	Testing		●	○		●				
		Strategic Planning and Analysis			●				●		
		Plutonium Technologies	○	○	○				●		
		Uranium Technologies	○	○	○				●		
		Lithium Technologies	○	○	○				●		
		High Explosives	○	○	○	○					●
		Tritium			○	○		●		●	
		NonNuclear Components	○		○	○	●	●		●	●
		System Assembly	○	○	○	○	●	●	○	○	○
		Support Technologies			○	○					
	Emergency Management & Response	NEST		○	○	○			○	○	
		FRMAC		○	○				○	○	
		AMS		○	○				○	○	
		ARAC		○	○				○	○	
		ARG		○	○	○			○	○	○
		Special Applications		○	○				○	○	○
	Special Projects & Partnerships	Education Initiatives		○	○	○	○	○			
		Weapons Transportation Safeguards Systems		○	○	○	●	○	○	○	○
		Extraordinary ES&H and General Site Remediation		○	○	○		●	○		
		Other		○	○	○	●	○		○	○
	Test Ban Readiness	Weapon and Weapon Effects Physics		○	○	○	●				○
		Predictive Capability and Modeling	○	○	○	○	○				
		Testing		○	○	○					
	NonProliferation, Arms Control, & Threat Assessment	Policy Support	○	○	○						
		Assessments and Technology Surprise	○	○	○	○	●	○	●	○	○
		Proliferation Response Technologies		○	○						
		Operational Support									
		Testing		○	○						
	Inertial Confinement Fusion	Indirect Drive with Glass Laser		○	○			○			
		Direct Drive with Glass Laser		○	○			○			
		KrF Laser Driver		○	○			○			
		Light Ion Beam Driver		○	○			○			
		Capsule Fabrication and Development		○	○			●		○	
	Technology Transfer	Precision Engineering and Advanced Manufacturing		○	○	○	○	○			
		Materials and Processes		○	○	○	○	●	●	●	○
		Microelectronics and Photonics		○	○	○	○				
		Computer Architectures and Applications		○	○	○	○				
		Energy and Environment		○	○	○		○	○	○	○
		Biomedical Technologies		○	○	○	○	○			
	the R&TD Program	Design Sciences and Advanced Computation	★	★	★	★	★	★	★	★	★
		Advanced Manufacturing Technologies & Capabilities		●	●	●	●	●	●	●	●
		Advanced Materials Sciences and Technologies		●	●			★	★	★	★

R&TD Program Elements

The content and scope of each of the nine **R&TD Program Elements** is summarized here to document their relationship with current missions, ongoing programs, and anticipated needs.

Design Sciences and Advanced Computation

- **Conceptual Design
and Assessment**

Our Capabilities in **Conceptual Design and Assessment** are exercised through the exploration of concepts and technologies that offer potential options for meeting future needs. Through these efforts, future weapons and components are conceived. Although these activities do not involve formal hardware development, they may include a limited amount of prototyping or experimentation to assess or demonstrate conceptual feasibility. These efforts are often computationally intensive. Current activities address all aspects of design, from components to full systems. Emphasis is placed upon the anticipation of future national security requirements and missions. Current areas of interest include, but are not limited to, advanced electromagnetic radiation, stealth, and enhanced safety features such as fire resistant pits, Insensitive High Explosives (IHE), insertable nuclear components, paste explosives, and advanced containment. These capabilities are critical to sustaining the longterm operational safety and the credibility of the nuclear deterrent. There are currently five focal areas within **Conceptual Design and Assessment**.

1. Sciences Supporting Stockpile Improvements
2. Advanced Design and Technology Assessment
3. Safety and Surety Technology Assessment
4. Device Disablement Assessment
5. Threat Assessment

- **Physics**

This **Program Element** addresses weapon physics, supporting physics research, physics for weapon components, and weapons' effects and simulation physics. These efforts maintain and enhance our knowledge of physical processes and enable the development of new options for meeting future defense needs. Modern nuclear weapon design relies on a thorough understanding of radiation transport, dense plasma physics, high temperature hydrodynamics, and the coupling between radiation and matter. Basic and applied research supplies both the theoretical models and experimental data for design and evaluation codes that simulate weapon performance, provide improved predictive capabilities, and allow the development of new concepts that form the basis for understanding survivability and lethality. In addition, these capabilities contribute to research areas ranging from condensed matter to plasma physics. Research is currently underway in seven areas.

1. Hydrodynamics
2. Radiation Physics
3. Plasma Physics
4. Nuclear Physics
5. Solid State Physics
6. Optical Physics
7. Chemical Physics

- **Computation and Modeling**

Computation and Modeling are essential to the development, enhancement, and maintenance of simulation codes and databases for the weapons program. These capabilities support work in theoretical physics, mathematical modeling, and software and algorithms. In addition, research is exploring parallel computer architectures, neural networks, and other new computer architectures, as well as the new computational methods that are needed to fully exploit the power of these advances. Distributed computing systems, based upon high speed data communications techniques, are also being explored. Areas of current interest in the application of these technologies include assessments of complex or unique accident scenarios, the reduction of reliance on underground testing, and improvement of predictive capability for weapons design and perfor-

mance, particularly in support of advanced surety enhancements. Most of the technology development in **Computation and Modeling** has dual benefit potential. Eight areas are under study.

1. Predictive Capability
2. Dynamic Response Models
3. 3D Simulation
4. Distributed Computing
5. Visualization Tools
6. Massively Parallel Processing
7. Component Design
8. Robotics Algorithms

Advanced Manufacturing Technologies and Capabilities

• System Engineering Science and Technology

These capabilities enable the integration of components and systems that are required to sustain the nuclear deterrent, for the incorporation of new technologies into weapon systems and stockpile support operations, and for the demonstration or prototyping of emerging technologies. Associated systems analysis capabilities guide research and development by enabling the monitoring and assessment of new technologies, external threats, command structures, stockpile configurations, mission requirements, and the national security implications of developments in each of these areas. Our capabilities in **System Engineering Science and Technology** are currently being exercised in support of Command and Control, Performance Instrumentation, Manufacturing Technology, and Safing, Arming, Fusing and Firing. Opportunities presented by the reduction of the strategic threat will also be used to explore component standardization, modularity, and reuse as possible means of increasing reliability while reducing both costs and waste generation. There are five primary areas of current study.

1. Safety, Security, and Use Control
2. Arming, Fuzing, and Firing
3. Advanced Electrical Subsystems
4. Manufacturing Technology
5. Robotics

• Electronics, Photonics, Sensors, and Mechanical Components

Our capabilities in **Electronics, Photonics, Sensors, and Mechanical Components** provide the enabling technologies behind the components and subsystems that control and operate nuclear weapons. Mechanical, electromechanical, and electronic devices are used in every nuclear weapon. Photonics will be a standard technology for many future uses. Photonic devices used in conjunction with microelectronic systems offer opportunities for improved safety, security, reliability, and information processing. One current interest is the further development of intelligent systems that monitor and diagnose the condition of a weapon with regard to aging, functional status, intrusion/tamper detection, and anticipated performance. Emphasis is also being placed on improved safety in abnormal environments, enhanced command and control, automated monitoring and inventory control, command disablement, and intelligent manufacturing based on the use of robotics. These technologies have great dual benefit potential and the primary focus is currently being directed in eight areas.

1. Microelectronics
2. Photonics
3. Power Sources
4. Radars
5. Packaging and Interconnects
6. Micromechanics
7. Aerodynamic Components
8. Sensors

Advanced Materials Sciences and Technologies

• Chemistry and Materials

The special nature of nuclear weapons requires a diverse range of materials expertise, facilities support, and technological capability. The specialized materials developed and used, the unique lifespan and reliability requirements, and the need to withstand extreme mechanical and thermal environments create a unique set of materials science challenges. Continuous research and technology development is required

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in the areas of metallurgy, ceramics and inorganics, organic materials and polymers, and composites. Current activities focus on tailored materials, while other topics of interest include the development of low toxicity alternative materials to reduce the environmental safety and health concerns associated with weapons production, maintenance, and dismantlement.

1. Metals
2. Ceramics and Inorganics
3. Polymers
4. Composites
5. Predictive Aging
6. Environmentally Conscious Processes

• Special Nuclear Materials

Our research in **Special Nuclear Materials (SNM)** enhances our understanding of the physical, mechanical, chemical, and thermodynamic properties of actinides such as uranium, neptunium, plutonium, protactinium, and americium. This knowledge is fundamental to the development of environmentally benign fabrication capabilities, including advanced and automated plutonium processing, casting, and machining technologies. These process technologies will improve weapon safety and reduce both waste generation and worker exposure. Other activity focuses on the compatibility between molten plutonium and various nonnuclear materials in exploration of future weapons safety enhancements.

1. Plutonium
2. Uranium
3. Salt (LiH/D)

• Tritium

Tritium is both an essential material in nuclear weapons and the proposed fuel for inertial fusion. This **Program Element** encompasses material science research that is relevant to the production, handling, and use of this limited life material and to ensuring its compatibility with other materials and components. The design, production, and fielding of gas transfer systems, for example, involves issues in materials characterization, joining technology, analytical mechanics, performance modeling, and aging phenomena.

There are currently four broad areas of study within this **Program Element**.

1. Gas Transfer Systems
2. Solid Storage Systems
3. Neutron Generator Tubes
4. Fusion Targets

• Explosives

Research and technology development in the area of **Explosives** includes expertise in high energy density materials and the associated detonation systems that enable nuclear detonations. A primary focus of the current effort is the development and application of Insensitive High Explosives (IHE) that will properly detonate weapons when desired, while also being highly resistant to unintentional detonation through handling accidents or other mishaps. These efforts seek materials, associated application techniques, and detonation systems that will offer improvements in safety, performance, and ease of environmentally sound disposal. Primary concerns include aging effects in explosives with long stockpile service lives and the reaction of these materials to abnormal environments.

1. Insensitive High Explosives
2. High Energy Density Materials
3. Detonators
4. Binders

The management of these **Program Elements** is guided by a single common strategy.

- **Assure that the core defense competencies that are embodied in the R&TD Program Elements properly align with and support the current needs of the Defense Programs Initiatives.**
- **Preserve essential core competencies, capabilities, and facilities through activities that use and challenge these capabilities in addressing critical national issues.**
- **Support the fundamental capabilities that are needed to develop new concepts and evolve options for addressing future national security needs.**

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- Explore new technologies that offer the potential for significant improvements in the performance of defense missions or that enable the development of necessary new concepts or capabilities.

While their primary role is to support ongoing Defense Programs Initiatives, the Program Elements also support solutions to critical issues such as national economic competitiveness.

Research and Technology Development Division DP-242

Defense Critical Technologies

The Research and Technology Development Division also oversees the **DOE Defense Critical Technologies Plan**, produced as directed by the Senate Armed Services Committee. The **DoD Key Technologies** and **DOE Defense Critical Technologies** are, respectively, those technologies that are critical to the qualitative superiority of US conventional weapons systems and those technologies that are similarly fundamental to the credibility of the US nuclear deterrent. As indicated by the Deputy Assistant Secretary for Military Application in his introduction to the *1992 DOE Defense Critical Technologies Plan*, the purpose of the **DOE Defense Critical Technologies List** is "to identify and describe the unique technological capabilities that are essential to maintaining the US nuclear deterrent" and "to establish an innovative investment strategy for DOE defense science and technology." The eighteen **DOE Defense Critical Technologies**, listed below, and the annual investments made in advancing them represent our commitment to improving our technological tools and performing our defense missions "better, faster, and cheaper" in the future. Funding for the development of these technologies is provided by various programs within Defense Programs.

1. Science of Complex Systems

This technology area includes all of the important physical and chemical theory and experimental data that must be incorporated into models and simulation codes describing complex systems, including weapon components and facilities. This technology relies on the key experimental capabilities that test predictive understanding of the models developed to describe these systems.

2. Modeling and Simulation of Complex Systems

This technology focuses on developing computer representations of complex realworld phenomena. Modeling and simulations, combined with scientific

theory and experimental testing form the scientific foundation for the examination, understanding, and prediction of complex systems behavior.

3. High Performance Computing

High Performance Computing encompasses the development of modern computing capabilities for nuclear weapons design, scientific and engineering simulation, control of intelligent systems, pattern and language recognition, computer integrated manufacturing, data collection and analysis, and data security. Emphasis is placed on the development of new, massively parallel, computing architectures and languages.

4. Nuclear Weapons Predictive Capability

Nuclear Weapons Predictive Capability includes the ability to assess the performance, reliability, safety, and effectiveness of nuclear weapons. It provides capability required to design weapons with safety or other technical modification that do not replicate existing devices yet still perform with confidence. It also supports the ability to predict weapon response to abnormal environments.

5. Safety Assessment and Engineering

Weapon safety technology includes the design, development, and deployment of weapon system architectures to improve safety of weapons. It also includes the systematic assessment of safety features for cost, benefit, and risk.

6. Use Control and Security

Use control is the set of positive measures, including procedures and hardware features, applied to nuclear weapons systems that facilitate rapid authorized use and protect against unauthorized use. Physical security encompasses the positive measures that prevent or delay an adversary from gaining access to a nuclear weapon during storage, transportation, and handling and includes sensors, coded switches, cryptography, high-density power sources, entry control systems, and *in situ* destruction of critical nuclear components.

7. NonProliferation and Verification

This area is characterized by a diverse array of monitoring technologies; encompassing the conceptualization, design, and development of sensors, signal processors, tamper resistant data storage and data communications, and systems integration on a wide variety of platforms, including satellite, airborne, and groundbased systems.

8. Dynamic Testing in Severe Environments

These technologies include the capability to conduct experiments under extreme conditions of temperature, pressure, and density, in the presence of intense radiation fields, strong electromagnetic interference, and difficult access.

9. High Energy Density Materials

This technology provides the ability to develop, produce, and process high energy chemicals including explosives, propellants, and pyrotechnics, including theoretical, computational, and experimental tools for characterizing the performance of energetic materials in normal and abnormal environments.

10. Laser Technology

This technology incorporates laser research and development for a wide variety of applications, including diagnostic instruments, inertial confinement fusion (ICF), laser isotope separation, the creation of hot-dense plasma for weapon physics studies, optical firing sets, fiber optic data transmission, remote sensing, and others.

11. Pulsed Power and Accelerators

Pulsed power "conditions" large quantities of energy (megajoules) by compressing it in time to higher power and converting it into various forms of directed energy such as neutral particles, photons, electrons, ions, or massive projectiles. Accelerators convert electrical energy into the kinetic energy of electrons and ions. These technologies reduce reliance on underground nuclear testing and enable weapons effects certification.

12. Microelectronics and Photonics

Microelectronics and Photonics provide the ability to design, develop, produce, and package microelectronic and photonic devices for information detection, processing, and transmission while exposed to extreme environmental conditions. These technologies also enable weapon safety, security, and use control; the monitoring of weapon "status;" flight guidance and control; automatic target recognition; and "smart" weapon systems; including the development of required materials such as semiconductors, superconductors, and insulators.

13. Nuclear Materials

These technologies provide the capability to produce and process the unique materials required for the nuclear weapons program, including uranium, plutonium, tritium, deuterium, lithium, and beryllium, as well as special isotopes used as tracers.

14. Engineered Materials

Engineered Materials provide the ability to develop and produce materials to meet specific property requirements. Materials are designed from an understanding of fundamental scientific principles and relationships. Material classes include special metal alloys, ceramic and metal matrix composites, polymer bonded fiber composites, ceramics, glasses, thin films, adhesives, and encapsulants.

15. Flexible Manufacturing

Flexible Manufacturing encompasses technologies required for integration into the reconfigured nuclear weapons complex to enable the production of smaller production quantities with shorter development cycles and increased reliance on commercial suppliers. These technologies also enable the enhanced integration of design, engineering, materials and process science, fabrication techniques, and manufacturing equipment, including automated materials handling and machine control technology, to an extent that has generally not yet been demonstrated in commercial industrial manufacturing.

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16. Environmentally Conscious Manufacturing

Environmentally Conscious Manufacturing involves developing, evaluating, testing, and implementing new manufacturing technologies that are environmentally benign and are characterized by the minimization of hazardous waste, reduced energy consumption, improved materials utilization, and increased worker safety.

17. Intelligent Machines and Robotics

Intelligent Machines and Robotics encompasses the development and implementation of intelligent machines and robotics technologies to meet the Department's small lot, high quality, reduced cost production needs and entails the incorporation of sensor and model based process control.

18. Waste Management

These technologies are associated with the separation, treatment, storage, disposal, and recycling of wastes associated with the manufacture or retirement of nuclear weapons and include final waste storage concepts such as vitrification of radioactive waste, geologic storage, and transmutation of waste.

The Research and Technology Development Division manages the relationship between the DOE Defense Critical Technologies and the R&TD Program Elements. The DOE Defense Critical Technologies are, in fact, subsets of the R&TD Program Elements.

As further indicated in the *1992 DOE Defense Critical Technologies Plan*, the "creativity and innovation that have made the US nuclear deterrent so effective can be applied to explore new concepts for nonnuclear weapons and defense, as well to address the elements of major social and economic issues facing this nation...computational simulations can design safer automobiles; remote sensing for verification and nonproliferation can be used for environmental assessments; and lasers are gaining importance in manufacturing." Although the primary mission of the Division is to maintain

the technological capabilities required to sustain the credibility of our nuclear deterrent, the efforts of the Division are directly applicable to a much wider range of challenges, including the enhancement of our national economic competitiveness.

Programmatic Relationships

Figure 1, on page 7, and Figure 2, on page 15, clearly illustrate the programmatic context for the R&TD Program Elements. Figure 1, entitled *Programmatic Relationships*, displays the interdependencies between the Defense Programs Initiatives and the R&TD Program Elements, as well as between the Program Elements and the other two technology clusters within the R&TD Program. Figure 2, entitled *Technology Correlations*, displays the correlation between the R&TD Program Elements and both the DOE Defense Critical Technologies, and the DoD Key Technologies. As these charts demonstrate, the Research and Technology Development Program provides significant benefit across a wide spectrum of the technological frontiers that are so crucial to the future of the Nation.

Figure 2:

Technology Correlations

Figure 2:

Technology Correlations

the R&TD Program Elements

the DOE Defense Critical Technologies

the DoD Key Technologies

Design & Assessment	Physics	Computation & Modeling	System Engineering	Components	Chemistry & Materials	Special Nuclear Materials	Tritium	Explosives
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Science of Complex Systems	◆	◆	◆			◆		◆
Modeling and Simulation of Complex Systems	◆	◆	◆					◆
High Performance Computing		◆	◆		◆			
Nuclear Weapons Predictive Capability	◆	◆	◆	◆	◆			◆
Safety Assessments and Engineering	◆	◆	◆	◆	◆		◆	
Use Control and Security		◆	◆	◆	◆			
NonProliferation and Verification		◆	◆	◆	◆	◆		
Dynamic Testing in Severe Environments		◆	◆					
High Energy Density Materials	◆	◆	◆					◆
Laser Technology		◆		◆	◆			
Pulsed Power and Accelerators		◆			◆		◆	
Microelectronics and Photonics		◆		◆	◆			
Nuclear Materials		◆	◆			◆	◆	
Engineered Materials		◆	◆		◆			
Flexible Manufacturing		◆	◆					
Environmentally Conscious Manufacturing	◆	◆	◆	◆	◆	◆		
Intelligent Machines and Robotics		◆	◆		◆	◆		
Waste Management	◆	◆	◆	◆	◆	◆	◆	
Computers		◆	◆	◆	◆			
Software			◆					
Sensors		◆	◆	◆	◆	◆		
Communications/Networks		◆	◆	◆	◆			
Electronic Devices		◆	◆	◆	◆			
Environmental Effects		◆			◆			
Materials and Processes		◆			◆	◆	◆	
Energy Storage		◆	◆					◆
Propulsion and Energy Conversion		◆	◆				◆	◆
Design Automation		◆	◆		◆			
Human/System Interfaces		◆	◆	◆				

Legend to Figure 2:

DIRECT CORRELATIONsignificant overlap in challenges, goals, and development strategies

INDIRECT CORRELATIONpotential for the R&TD Program Element to provide significant benefit

**DEFENSE PROGRAMS
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the **R&TD Program Elements**

The pages that follow contain summaries of the nine **R&TD Program Element Plans for Fiscal Year 1993**. These plans, completed in the Spring of 1993, define the technology areas being coordinated through the efforts of the Research and Technology Development Division. More importantly, these plans further examine and document the applicability of these capabilities to meeting vital national needs. These capabilities represent a unique national resource, accumulated over a half century of dedication to meeting vital national security needs through scientific and technological excellence. Today, the Division is coordinating the capabilities necessary for the appropriate reduction of the stockpile, while continuing efforts to preclude the possibility of technological surprise. While the three Defense Programs National Laboratories have an excellent record of stewardship over the nuclear weapons stockpile, we continue to work to enhance the capabilities needed to support and maintain the enduring stockpile. In addressing the continuing spread of military technologies and the proliferation of nuclear capabilities, the Division has and will continue to contribute to a wide variety of arms control and verification efforts and to assist intelligence efforts with a variety of unique technical interpretation and

assessment capabilities. With regard to the regional threats posed by a dynamically changing multipolar world, the Division has enabled the development of capabilities that are uniquely valuable in addressing conventional military and security issues. Finally, with regard to emerging economic and social challenges, the capabilities coordinated and maintained through the Division's Research and Technology Development Program have contributed to the transfer of technology for drug detection and interdiction, the improvement of domestic manufacturing methods, new and specialty materials, alternative energy sources, combustion research, advanced drilling technologies for the petroleum and geothermal industries, biomedical technologies, genome mapping, global economic and environmental modeling, support to educational institutions, technology for the exploration of space, and advanced transportation modeling. In this and many other ways, the Division works with the Laboratories to maintain vital core competencies and capitalize on the public investments that have already been made, while simultaneously addressing the crucial missions and responsibilities of the Department in this post Cold War Era.

DEFENSE PROGRAMS
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Conceptual Design and Assessment

A. Programmatic Importance to DOE Defense Missions:

Conceptual Design and Assessment supports the exploration of new concepts in weapon design. While some hardware development and experimentation is conducted, most of these activities involve conceptual studies and computer analysis using the most advanced hardware and applications software available; the acquisition and development of which is supported mainly by the **Computation and Modeling Program Element**. Concepts under consideration in this Program Element range in complexity from relatively minor modifications in the components of existing weapons to major changes in warhead subsystems, or to entirely new physics designs for a proposed or candidate weapon. This Program Element is generally focused on investigations of forward-looking weapon and weapon component concepts, as opposed to concepts driven by formal military requirements or Stockpile Improvement Programs.

The main emphasis of this Program Element is on ideas that have the potential to lead to either a substantial advance in the performance, military utility, or surety of nuclear weapons, or to a significant reduction in life-cycle costs or the emission of hazardous materials into the atmosphere. At such time that a new concept matures to the point of inclusion in a formal directed study, the concept would be transferred into a program outside of the **Research and Technology Development Program**, such as a **Stockpile Stewardship Program**, or, alternatively, into another **R&TD Program Element**, such as **Systems Engineering Science and Technology**.

Current emphases in this Program Element are on enhanced surety, hazardous materials substitution (including SNM substitution where appropriate), new weapon capabilities, and prevention of technological surprise. Examples of this work include:

- new materials for fire-resistant pits;
- methods to greatly enhance electrical nuclear detonation safety;
- innovative concepts to initiate prompt detonation of explosives that offer greatly enhanced safety;
- concept design studies, arising out of the experiences during and after the Gulf War that indicated potential military utility for types of nuclear weapons not currently in the stockpile; and
- nuclear designs for enhanced surety weapons

The boundary between **Conceptual Design and Assessment** and formal development programs or other Program Elements is not well defined, but, in general, a concept is supported by this Program Element only through a "proof of principle" demonstration. Because this Program Element looks beyond proven concepts and outside of traditional methods, it provides the new ideas needed to evolve and improve the stockpile, to meet the evolving needs of the military in a timely manner, and to maintain technological superiority. This Program Element is also of critical importance to the Office of Intelligence and National Security to aid in the assessments of possible nuclear weapon proliferation activities. This expertise proved its high value to the Nation in the aftermath of the Gulf War. Persons needing additional information are referred to the classified Program Element Plan for Conceptual Design and Assessments; from which this summary was extracted.

NPP&A PROGRAMS RESEARCH and TECHNOLOGY DEVELOPMENT

B. Major Activities, Enablers, and Benefits in the Area of Conceptual Design and Assessment:

Major Activities		Enablers and Benefits
focal area: SAFETY	Enhanced Nuclear Safety	paste extrudable High Explosive (HE) for main charge, gas transfer, and compressed magnetic field power sources; Insensitive High Explosive (IHE) retrofits; advanced IHE formulations; protected volumes; further development of Enhanced Electrical Nuclear Detonation Safety (ENDS)
	Intrinsic Nuclear Safety	pit disable and insertable nuclear material
	Environmental Safety and Health	Fire Resistant Pits (FRP), pit reuse, precision plutonium casting, and all oralloy nuclear assemblies
focal area: FORWARD-LOOKING CONCEPTS	Stealthy Standoff Glide Bomb	bomber survivability, hypersonic release, precision terminal guidance, and sensor/data fusion
	Fine Resolution Imaging Radar	precision weapon guidance, detection of buried targets, and detection of proliferation activities
	Advanced Command and Control	remote enable/disable and enhanced use control
	Global Verification and Location System	treaty verification, tags, realtime inventory, and the GPS-based precision strike locator (SCREAMER)
	Miniature Navigators	precision delivery
focal area: DESIGN WITHOUT TESTING	Nuclear Design/Components	increased design margins and UGT/AGEX data correlation
	Electronic/Mechanical Components	inherent reliability, modular components, and design for testability

Note:

Enablers and Benefits are, in this context, activities, programs, objectives, or technologies that either enable or benefit or are enabled or benefitted by work in **Conceptual Design and Assessment**.

The **Key Challenges** and **Milestones** indicated above are based on the assumption of a "stable" funding profile over the duration of the projects. Significant variations in funding during this period could obviously force reassessment of project goals and schedules.

C. Key Challenges and Milestones in the Area of Conceptual Design and Assessment:

Key Challenges	Related Initiatives	Major Milestones
IHE and FRP Safety/Security Upgrades for the Enduring Stockpile (Los Alamos National Laboratory)	Stockpile Stewardship	Testing Completed Fourth Quarter of 1996
Three Dimensional Accident Response Assessments (Los Alamos National Laboratory)	Stockpile Stewardship	Three Dimensional Analyses Completed Fourth Quarter of 1994

DEFENSE PROGRAMS RESEARCH and TECHNOLOGY DEVELOPMENT

Key Challenges	Related Initiatives	Major Milestones
Disablement Device (Los Alamos National Laboratory)	NonProliferation and Arms Control	Disablement Design Completed Fourth Quarter of 1995
Virtual Design (Los Alamos National Laboratory)	Test Ban Readiness	First Virtual Design Cycle Completed Fourth Quarter of 1996
UGT/AGEX Bridging Experiments (Los Alamos National Laboratory)	Test Ban Readiness	Bridging Experiments Completed Fourth Quarter of 1996
NIMP Device Mix Determination (Los Alamos National Laboratory)	Test Ban Readiness	Testing Completed Fourth Quarter of 1996
Stealthy Standoff Glide Bomb (Sandia National Laboratories)	Stockpile Stewardship	Conceptual Design Defined Second Quarter of 1994
Global Verification and Location System (GVLS) (Sandia National Laboratories)	Stockpile Stewardship and NonProliferation	Complete Design Defined for a GPS-based System Fourth Quarter of 1994
Strike Assessment and Remote Enable System (SCREAMER) (Sandia National Laboratories)	Stockpile Stewardship	Complete Design Definition Fourth Quarter of 1994

D. Potential Benefit to DOE Energy Programs:

The systems conceptualized through this Program Element are intended to meet the specific missions and requirements of nuclear weapons. As such, these systems *per se* are not expected to provide benefit to energy programs; however, the science of complex systems can provide significant benefit to the study of complex energy systems.

E. Potential Benefit to the Department of Defense:

As discussed above, the capabilities developed in this Program Element provide indirect benefit to the development and assessment of conventional

military systems. Specific benefit to the DoD results from the precision guidance and global inventory concepts being examined in this Program Element.

E. Potential Benefit to National Economic Growth:

As discussed above, the capabilities developed in this Program Element provide indirect benefit to the development and assessment of systems having commercial importance. Specific benefit to commercial systems will be derived from global real-time inventory technology, which will enable improved security during shipment of high-value items.

DEFENSE RESEARCH AND TECHNOLOGY DEVELOPMENT

Physics

A. Programmatic Importance to DOE Defense Missions:

Physics principles largely govern the behavior and performance of nuclear weapons and many of the associated components. The **Physics Program Element** nurtures the essential scientific underpinnings needed to design and evaluate complex nuclear weapon systems and subsystems. It also provides the foundation for many of the unique facilities and capabilities used to test and evaluate these systems, as well as perform experiments that benchmark the computer codes that provide the basis for Nuclear Weapon Predictive Capability. Nuclear Weapon Predictive Capability is the ability to correctly assess the performance, reliability, safety, and effectiveness of nuclear weapons. To properly prepare for further constraints on the testing of nuclear weapons, much improvement in existing predictive capability is needed to ensure that a modified or new weapon will function as intended and to gain confidence that permissible subscale testing will be sufficient to ensure the continuing credibility of the stockpile. This issue may be the most challenging requirement placed upon the US Nuclear Weapon Program.

The laws of physics govern virtually every phase of weapon design, engineering, testing, and certification. The understanding sustained by the work within this Program Element touches every aspect of maintaining a credible deterrent. Physics principles not only underpin the design and testing of nuclear weapon systems, they also underpin many of the unique manufacturing processes for weapon components. These principles also form the basis for predicting the effects of nuclear explosives on

military targets and the vulnerability of nuclear weapons to nearby nuclear explosions. This Program Element, along with the **Computation and Modeling Program Element**, is the centerpiece of the Nuclear Weapon Program.

There are ten key subelements within the **Physics Program Element**:

- **Hydrodynamics** focuses on understanding the detailed effects of high-explosive detonations and material flow during the implosion of the nuclear fuel or surrogate material and on assessing the response of weapon cases and components during device operation and accidents.
- **Radiation Physics** models the flow of photons, neutrons, and x-rays through interacting materials and complex geometries. This capability is essential for nuclear design, weapons effects studies, test facilities design, interpretation of weapons and development tests, and detector development for diagnostics.
- **Atomic Physics** forms the basis for calculations of the interaction of electrons, ions, x-rays, and photons with matter. It is used extensively in the design of intense x-ray sources, lasers, and pulsed power devices. It is an essential element of calculations of radiation flow through interacting materials and through complex geometry systems bounded by interacting materials, of plasma physics, and of weapon effects models and codes.
- **Nuclear Physics** maintains the databases required for the orderly evolution of weapon design and nuclear diagnostics. It also includes calculations and measurements of nuclear cross sections and the development of neutron transport models and codes.
- **Plasma Physics** is instrumental in the interpretations of experimental observations of full-scale nuclear tests and of laboratory experiments that employ lasers or pulsed power sources to benchmark

DEFENSE PROGRAMS RESEARCH and TECHNOLOGY DEVELOPMENT

codes used in nuclear design. It guides the design of targets for Inertial Confinement Fusion (ICF) and the interpretation of ICF experimental results. It underlies the design of various components used in pulsed power systems; the development of high-temperature, highly ionized, intense x-ray sources; the development of discharge-excited lasers for materials processing and characterization; and the development of improved plasma processes for cleaning surfaces, for depositing thin films of special materials, and for chemical micromachining.

- **Condensed Matter Physics** includes the measurement of equation of state of materials for conditions of severe temperature and pressure, which are necessary for nuclear and non-nuclear component design. It also underlies semiconductor and dielectric physics, which guides the design, fabrication, and testing of special purpose microelectronic and photonic devices.
- **Chemical Physics** guides the development of gas lasers; the development of chemical processes for materials synthesis, cleaning, deposition, and

etching; and the simulation and modeling of the response of explosives.

- **Astrophysics** is studied because the similarities with nuclear weapon physics provides insight that leads to improved weapon design codes.
- **Optical Physics** supports research and development of lasers and photonic devices, components for direct optical initiation of pyrotechnics and explosives, laser-based materials processing methods, LIDAR for remote optical detection of trace chemicals in the atmosphere for hazardous waste site characterization, and laser imaging and ranging techniques.
- **Pulsed Power Technology** is indispensable for intense x-ray sources that are used to assess the effects of ionizing radiation on weapon components, to validate weapon design physics understanding and codes, and to evaluate the hydrodynamics of nuclear assembly implosions.

These capabilities help sustain and support every defense mission of the DOE.

B. Major Activities, Enablers, and Benefits in the Area of Physics:

Major Activities		Enablers and Benefits
focal area: WEAPON PHYSICS	Hydrodynamics	implosion behavior, weapon design codes, spallation, hydroinstabilities, and High Explosive (HE) energy coupling
	Radiation Physics	weapon design codes
	Atomic Physics	opacities, x ray spectra, energy levels and oscillator strengths of multiply ionized atoms, and electron and ion cross sections
	Nuclear Physics	improved nuclear cross section database for weapon design codes
	Plasma Physics	the interpretation of fullscale nuclear tests and laboratory simulations of weapons physics
	Condensed Matter Physics	materials stability and equation of state for extreme temperatures and pressure
	Astrophysics	understanding the physics of systems with similarities to nuclear explosions

DEFENSE PROGRAM RESEARCH AND TECHNOLOGY DEVELOPMENT

Major Activities		Enablers and Benefits
focal area: COMPONENT PHYSICS	Hydrodynamics	safety assessment, crash simulations, strong shock, and armor
	Radiation Physics	assessments of the effects of ionizing radiation
	Semiconductor Physics	radiation resistant microelectronic and photonic devices
	Chemical Physics	chemical vapor deposition, gas lasers, and thermal decomposition of High Explosives
	Plasma Physics	plasma etching, cleaning, and thin film deposition
	Optical Physics	lasers, FALCON, vision science, and robotic vision
WEAPON EFFECTS PHYSICS	Radiation Physics	predictive capability
focal area: FACILITIES PHYSICS	Pulsed Power Technology	x-ray and weapons physics, particle accelerators, laser excitation, component certification, simulator development, and benchmarking weapon design codes
	Lasers	weapons physics, atomic physics data, and weapons effects simulations
	Accelerators	weapons effects simulation, radiography, materials composition and structure analysis, waste conversion and transmutation, SNM and tritium production, and materials modification

Notes:

The **Enablers and Benefits** listed above are activities, programs, objectives, or technologies that either enable or benefit or are enabled or benefitted by work in **Physics**.

The **Key Challenges and Milestones** listed below are based on the assumption of a "stable" funding profile over the duration of the projects. Significant variations in funding during this period could obviously force reassessment of project goals and schedules.

C. Key Challenges and Milestones in the Area of Physics:

Key Challenges	Related Initiatives	Major Milestones
Hydrodynamic Instability and Turbulent Mix Physics on NOVA (Lawrence Livermore National Laboratory)	Stockpile Stewardship and Test Ban Readiness	Understand Mode Coupling and Multimode Growth of Turbulence Fourth Quarter of 1993 Measure Mix Width in Turbulent Regime Fourth Quarter of 1994

DEFENSE PROGRAMS RESEARCH AND TECHNOLOGY DEVELOPMENT

Key Challenges	Related Initiatives	Major Milestones
Implosion Hydrodynamics (Los Alamos National Laboratory)	Stockpile Stewardship, Test Ban Readiness, and Inertial Confinement Fusion	Perform Hydrotest Experiments with Pit Material Fourth Quarter of 1993 Complete Hydrotest Experiments with Several SNM Simulants Fourth Quarter of 1997
Plutonium Melt Curve Determination (Lawrence Livermore National Laboratory)	Stockpile Stewardship and Test Ban Readiness	Measure Melt Curve for Pressures up to 300 GPa and Temperatures up to 6000 K Fourth Quarter of 1993
Equation of State for Hot Expanded Plutonium (Lawrence Livermore National Laboratory)	Stockpile Stewardship and Test Ban Readiness	Measure for 12 to 18 g/cm ³ and 0.2 to 1.0 eV Fourth Quarter of 1994
Radiation Physics Experiments (All Three DP National Laboratories)	Stockpile Stewardship and Test Ban Readiness	Complete Experimentation on SATURN to Benchmark Codes over Extended Temperature Range Fourth Quarter of 1997
High-Z Opacity Measurements (Los Alamos National Laboratory)	Stockpile Stewardship, Test Ban Readiness, and Inertial Confinement Fusion	Complete Experimentation on NOVA and/or SATURN Fourth Quarter of 1995
High-Z Opacity Models (Lawrence Livermore National Laboratory)	Stockpile Stewardship, Test Ban Readiness, and Inertial Confinement Fusion	Improve Accuracy and Benchmark with NOVA Fourth Quarter of 1994
Determine Energy Levels & Oscillator Strengths for Key Transitions & Benchmark Transport Codes (Lawrence Livermore National Laboratory)	Stockpile Stewardship, Test Ban Readiness, and Threat Assessment	Expand the Database for Z up to 92 Fourth Quarter of 1997
Plasma Etching Predictive Capability (Sandia National Laboratories)	Stockpile Stewardship and Reconfiguration	Apply to Adaptive Process Control of Microelectronic Processing Equipment First Quarter of 1995
Demonstrations of Pulsed Power Components Enhancements (Sandia National Laboratories)	Test Ban Readiness and Inertial Confinement Fusion	Contact Technology for 10 ⁶ Shot Photoconducting Semiconductor Switch Fourth Quarter of 1993 Scalable Triggered Plasma Opening Switch Fourth Quarter of 1993 10 ⁷ Shot 50 kV/cm Photoconducting Semiconductor Switch Fourth Quarter of 1995 Cathode Technology for 2 MV/cm without Electron Emission Fourth Quarter of 1996

Key Challenges	Related Initiatives	Major Milestones
Vision Science and Pattern Recognition (Sandia National Laboratories)	Stockpile Stewardship, Reconfiguration, and NonProliferation	Apply New Understanding to Robotics, Process Control, Chemical Sensor Arrays, and LIDAR Fourth Quarter of 1994
UltraShort Pulse Laser (Lawrence Livermore National Laboratory)	Stockpile Stewardship and Test Ban Readiness	Demonstrate 1 Joule, 100 fsec, 10^{20} W/cm ² Capability Fourth Quarter of 1996
Time Resolved Gamma Spectroscopy (Lawrence Livermore National Laboratory)	Stockpile Stewardship and Test Ban Readiness	Demonstrate 1 to 25 MeV, 100 keV Spectral Resolution, 250 psec Temporal Resolution Capability Fourth Quarter of 1996
FXR Upgrade (Lawrence Livermore National Laboratory)	Stockpile Stewardship and Test Ban Readiness	Demonstrate Greatly Reduced Spot Size and 2X Increased Current Fourth Quarter of 1994
Interface Stability Physics (Sandia National Laboratories)	Stockpile Stewardship and Reconfiguration	Improved Understanding of Physics Fourth Quarter of 1998 Apply to Component Reliability Ongoing Efforts
Nanocluster Science and Applications (Sandia National Laboratories)	Stockpile Stewardship, Reconfiguration, and Site Restoration	Demonstrate Application to a Microelectronic or Photonic Device Fourth Quarter of 1994 Apply to Waste Stream Treatment Fourth Quarter of 1995
Triggerable Plasma Opening Switch for Pulsed Power Systems (Sandia National Laboratories)	Stockpile Stewardship and Test Ban Readiness	Demonstrate less than 3 nsec Jitter on the MITE Accelerator Fourth Quarter of 1995
Assess the Utility of the Russian ANGARA V Imploding Plasma System (Sandia National Laboratories)	Stockpile Stewardship and Test Ban Readiness	Demonstrate Utility on the SATURN Accelerator Fourth Quarter of 1996
Solid State, Megavolt, High Current, Low Inductance Switches (Sandia National Laboratories)	Stockpile Stewardship and Test Ban Readiness	Demonstrate Utility to Replace Gas and Liquid Dielectric Spark Gaps on Low Impedance Accelerators Fourth Quarter of 1998
High Average Power Ion Beam Systems for SNM Production (Sandia National Laboratories)	Reconfiguration	Complete Design Definition of the System Fourth Quarter of 1999
JUPITER Imploding Plasma Load for 15 to 30 keV X-Ray Simulator (Sandia National Laboratories)	Stockpile Stewardship and Test Ban Readiness	Complete Characterization, Optimization, and Transfer System to Users Fourth Quarter of 2001

D. Potential Benefit to DOE Energy Programs:

The DOE energy programs will benefit both directly and indirectly from this work. Energy programs that will benefit directly from this program element include:

- **Magnetic fusion energy** through the plasma physics activities.
- **Nuclear energy** through the nuclear physics activities.
- **Hazardous waste destruction** through the pulsed power activities.
- **Photovoltaics** through the semiconductor physics activities.
- **Environmental science** through the chemical physics activities and lasers for remote monitoring with LIDAR systems.
- **Catalysis and photocatalysis** systems.
- **Use of nanoclusters** for waste conversion and treatment.

E. Potential Benefit to the Department of Defense

Similarly to the impact on DOE energy programs, much of the impact of this Program Element on the DoD is indirect, via other Program Elements. Direct benefits include:

- **Hydrodynamics** and related codes are used to evaluate the dynamic fracture of military systems by conventional munitions, as well as to design improved armor.
- **Pulsed power technology** is important to the Defense Nuclear Agency (DNA) for weapons effects simulation facilities. Pulsed power technology is also the basis for hypervelocity munitions.
- **Radiation transport physics** and related codes are used by the DNA to predict the effects of radiation on military systems.
- **Lasers** have military application in battlefield sensing of chemical and biological agents via

LIDAR. They also have applications for remote detection and characterization of atmospheric pollution that may indicate proliferation of weapons of mass destruction by an adversary country.

F. Potential Benefit to National Economic Growth:

Similarly to the impact on DOE energy programs and on DoD systems and initiatives, the impact of this program element on the economic growth of the Nation is primarily indirect, via other Program Elements. Direct benefits include:

- **Semiconductor physics** is the basis for advancements in high performance microelectronic and photonic devices.
- **Plasma physics** is the basis for plasma etching equipment that is indispensable in the manufacturing of modern microelectronic devices. It is one of the technologies that pace the movement to the next-generation of higher density circuits.
- **Lasers** are used in manufacturing to cut, join, and surface treat materials. Improved efficiency and reduced cost is often the key to open this technology to new applications.
- **Application of nanocluster materials** to catalytic processes and waste stream clean up.

Computation and Modeling

A. Programmatic Importance to DOE Defense Missions:

This Program Element ensures the development and maintenance of computation and modeling capabilities that are essential to the design, production, testing, and certification of nuclear weapons. In the broadest terms, **Computation and Modeling**, through the simulation and modeling of complex systems, reduces overall program costs by assisting with risk reduction, early in the system life cycle, and by reducing the requirements for physical testing.

A nuclear weapon is a complex system, consisting of a large number of components and subsystems. When a weapon is fired or during an unintended or accidental event, the actions of these components and subsystems are tightly coupled. The complexity of structure, function, and interaction in these components prevents their efficient design, at any reasonable cost, without the use of extensive computational support. In addition, these systems and components must consistently meet the most demanding requirements for safety and reliability and continue to function with high precision, throughout the course of their stockpile service life, which may be decades in length and include exposure to relatively severe environmental, handling, and transportation stresses.

Once a weapon enters the stockpile, opportunities for direct inspection and testing are limited and expensive. Maintaining this extreme level of product reliability, with minimal direct testing and at a reasonable cost, requires computational modeling at every stage of the design, production, and

service life of the weapon to predict and assess product performance under a wide range of conditions and situations.

Virtually all of the Program Elements of the Office of Research and Advanced Technology, and all of the DOE defense initiatives and programs that these Program Elements support, are heavily dependent on the core capabilities furnished by the activities of the **Computation and Modeling Program Element**. Areas of particularly critical dependence include:

- the design of the nuclear assembly;
- the design of non-nuclear components;
- testing required to assess system, subsystem, and component performance;
- experimentation necessary to enhance our understanding of the underlying physics of systems, subsystems, and components;
- the correlation of physical simulations to actual threats;
- the design of engineered materials and the processes used to make and form them;
- the control of intelligent manufacturing equipment and robotics for handling hazardous materials and assembly of systems;
- safety assessments, including probabilistic risk assessment (PRA);
- support for emergency response activities;
- the assessment of weapon performance for various targeting scenarios; and
- the assessment of weapon vulnerabilities

Computation and Modeling plays an important role in all of these areas. For example, computational analysis is critical to safety assurance studies. These studies ensure that weapon systems neither function nor expose the environment to

hazardous materials in accident scenarios. Also, with tighter constraints being placed upon the testing of nuclear weapons, our ability to certify the vulnerability of components to radiation, without underground testing, will be even more important than it has been in the past. More sophisticated simulation and modeling capabilities will be essential. **Computation and Modeling** is also critical in designing weapon transportation and storage systems, and in evaluating weapon survivability against nuclear defense measures.

In production of new weapons or the manufacturing of replacement components, **modeling** is fundamental to agile manufacturing and will be a cen-

terpiece of the reconfigured complex, where production processes will be modeled and integrated, by Computer Aided Design (CAD) and Computer Aided Manufacturing (CAM), to ensure product reliability, at low cost, under low volume and flexible production conditions. **Computation and Modeling** is also being used to address evolving environmental safety and health concerns.

Virtually all the missions of the Department are dependent on **Computation and Modeling**. The Offices of Security Affairs, Intelligence and National Security, and Environmental Restoration and Waste Management also rely on the capabilities maintained by this program element.

B. Major Activities, Enablers, and Benefits in the Area of Computation and Modeling:

Major Activities		Enablers and Benefits
focal area: COMPONENT DESIGN & TESTING	the Nuclear Device	hydrodynamics, hydro mix, magnetohydrodynamics, coupled hydrostructural dynamics, coupled hydrothermal dynamics, radio-chemical dynamics, radiation transport, neutron transport, ion transport, and EOS
	NonNuclear Components	hydrodynamics, coupled hydrostructural dynamics, coupled hydrothermal dynamics, EOS, structural dynamics, strong shock, fluid dynamics, turbulence, flight dynamics, aerodynamic design, and penetration mechanics
focal area: SYSTEM LEVEL SURETY ASSESSMENT	Safety	accident response simulation, crash simulations, coupled hydrothermal dynamics, structural dynamics, PRA, EOS, thermal decomposition, flammability, and fragmentation
	Security	use control assessments, robotics software, physical security models, SNM operations, and threat assessments
focal area: WEAPON EFFECTS	Lethality	structural dynamics, coupled hydrostructural dynamics, massively parallel, radiation transport, and EMP generation
	Vulnerability	melt and spall models, radiation transport, and coupled effects between radiation and EMP, radiation and high strain, and radiation and the strain rate
focal area: OPERATIONS	Transportation	crash worthiness, shipping casks, and PRA
	Storage	robotics for handling, maintenance, and monitoring
	Dismantlement	robotics for disassembly, automatic planning and programming

Major Activities		Enablers and Benefits
focal area: MANUFACTURING	Process Definition	models of complex processes, virtual prototyping, and flexible configurations
	Intelligent Machines	adaptive machine operation, sensor and model based control, automatic planning and programming, and robotic assembly
	Design	substitution of safer materials and processes
	Failure Analysis	failure mode assessment

Note:

Enablers and Benefits are, in this context, activities, programs, objectives, or technologies that either enable or benefit or are enabled or benefitted by work in **Computation and Modeling**.

C. Key Challenges and Milestones in the Area of Computation and Modeling:

Key Challenges	Related Initiatives	Major Milestones
Three Dimensional Eulerian Codes for Shear and Distorted Flow Simulation and Nuclear Safety Assessment (Los Alamos National Laboratory)	Stockpile Stewardship and Test Ban Readiness	Complete Shear & Distorted Flow Code Second Quarter of 1994 Three Dimensional High Explosive Initiation Model Applied to Nuclear Safety Assessments First Quarter of 1996
Three Dimensional Coupled HydroStructural Codes (Los Alamos & Sandia National Laboratories)	Stockpile Stewardship and Test Ban Readiness	Limited Capability Third Quarter of 1994 Implemented in Most Areas of Weapon Design First Quarter of 1997
Parallel Libraries for Solutions of Large Linear Systems (All Three DP National Laboratories)	Stockpile Stewardship	10X Increase in Capability to Solve Complex Problems First Quarter of 1994 100X Increase in Capability First Quarter of 1997 1000X Increase in Capability First Quarter of 2000
Direct Simulation of Turbulence, Turbulent Combustion, & the Deflagration to Detonation Transition for Design & Safety Assessments (All Three DP National Laboratories)	Stockpile Stewardship	Application to Weapon Design and Safety Assessment First Quarter of 1996

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Key Challenges	Related Initiatives	Major Milestones
Codes for Simulation of Unsteady Fluid Dynamics in Inflating Parachutes (Sandia National Laboratories)	Stockpile Stewardship	Application to Parachute Design First Quarter of 1996
Improved Fragmentation Response Model (Sandia National Laboratories)	Emergency Response	Meet Established Requirements Second Quarter of 1995
Smart Adaptive Software for SelfProgramming Robots in Manufacturing, Stockpile Maintenance, & Dismantlement (Sandia National Laboratories)	Stockpile Stewardship and Reconfiguration	Limited Capability for Selected Operations First Quarter of 1994 Greatly Expanded Capabilities First Quarter of 1996 Application to Most Processes in the Complex First Quarter of 1999
Computational Fluid Dynamics (Sandia National Laboratories)	Stockpile Stewardship and Reconfiguration	Three Dimensional Calculations with 10^8 Cells and One Day Turnaround First Quarter of 1996 Predictive Model for Complex Geometry CVD Systems First Quarter of 1996 Predictive Model for the Majority of Welding Problems First Quarter of 1995
Crash Simulations Model to Predict Response of Structures in Accidents (All Three DP National Laboratories)	Special Projects and Partnerships	10X Improvement in Complexity Capability First Quarter of 1995 100X Improvement First Quarter of 1997 1000X Improvement First Quarter of 1999
Accident Response Codes in Three Dimensions for Nuclear Weapons (Los Alamos National Laboratory)	Stockpile Stewardship and Test Ban Readiness	Massively Parallel Processing to Allow Realistic Assessments of Nuclear Weapon Accident Scenarios First Quarter of 1996 Continuous Evaluation of Stockpile Safety Beginning in the First Quarter of 1996

Note:

The **Key Challenges** and **Milestones** indicated above are based on the assumption of a "stable" funding profile over the duration of the projects. Significant variations in funding during this period could obviously force reassessment of project goals and schedules.

D. Potential Benefit to DOE Energy Programs:

Dating from the first computers, the Defense Programs National Laboratories have driven both hardware and software development. The capabilities that exist in these institutions, to model and simulate complex problems, is unmatched elsewhere. Many of these capabilities are applicable to energy and environment problems. The capabilities of interest to DOE Energy Programs include:

- the modeling manufacturing processes to improve energy efficiency;
- the modeling and simulation of combustion processes to improve efficiency;
- the modeling of secondary gas recovery to improve performance and reduce cost;
- Monte Carlo simulations and massively parallel models of molecular dynamics for the design of engineered molecules and materials, including catalysts;
- computational fluid dynamics models for combustion and materials synthesis and processing;
- probabilistic risk assessments (PRA) for nuclear power reactor safety assessments; and
- simulations of environmental process to assess effect of carbon fuels combustion on the environment, including CO₂ build-up and global climate warming.

E. Potential Benefit to the Department of Defense

Many of the computational capabilities developed for nuclear weapon design, testing, and evaluation are directly applicable to the design and assessment of advanced conventional munitions and military systems. The DoD presently funds about a billion dollars per year of R&D at the Defense Programs National Laboratories. Much of this funding is attracted by the superior ability of these institutions to bring meaningful solutions to complex system problems through their broad

simulation and modeling strengths. Areas of high interest to the military include:

- agile manufacturing using intelligent machines for affordability;
- more reliance on computation, prior to prototyping and physical testing, to reduce cost and identify problems before expensive tooling;
- the development of substitute manufacturing processes that reduce cost, minimize harmful effects on the environment, and enhance safety;
- massively parallel computers and software;
- quality assurance of software;
- neural nets for process control/optimization;
- data fusion protocols to handle large data streams efficiently;
- hydrodynamic codes to simulate armor and anti-armor effectiveness;
- direct simulation of turbulence, turbulent combustion, and deflagration-to-detonation transition in formats useful for conventional munitions design and safety assessments; and,
- as described below, assistance to the defense industries in intelligent/agile manufacturing.

F. Potential Benefit to National Economic Growth:

Although scientific computing represents a relatively small fraction of the total use of computers, it is the segment that drives advances in the market. Historically, DOE Defense Programs has been the driving, dominant, customer for advanced supercomputing; however, until recently, the Defense Programs National Laboratories have not made an integrated, coordinated, effort to transfer their simulation and modeling capabilities to universities and industry. With the increased emphasis on technology transfer and economic growth, this situation is changing. Areas of special interest to the private sector include:

- computer design of complex manufacturing processes;
- computer design of catalytic and biological materials;

- the design of safer transportation systems;
- shortening the span of time between product definition and realization by incorporating processing models into the design process;
- concurrent engineering software that allows multiple workstation users, at diverse geographic locations, to work interactively on computer-aided design and computer-aided manufacturing process plans, tool path plans, and numerical control instructions for milled parts;
- Robot Independent Programming Environment (RIPE) and Robot Independent Programming Language (RIPL) software that reduces the time needed to develop intelligent robotic systems;
- software for self programming of robots, where an expert system examines a solid model of an assembly and then automatically determines an assembly plan and writes the robotics program to perform the operation; and
- software for tool path planning that is embedded into a commercial CAD/CAM system and assists manufacturing engineers in developing process plans, tool path plans, and numerical control instructions for milled parts.

System Engineering Science and Technology

A. Programmatic Importance to DOE Defense Missions:

This Program Element provides the essential engineering design and development activities, including manufacturing research and development, that support multiple programs and initiatives of atomic energy defense. Such activities result in the needed engineering assessments associated with new weapon and weapon component concepts and with potential stockpile improvements. This program element also maintains the design, engineering, and testing infrastructure needed to engineer improvements into the stockpile. In addition to being the source of technologies for new weapon development and stockpile improvements, it is the receptor of new technologies and processes from other program elements.

System Engineering Science and Technology is responsible for determining engineering feasibility and for assessing the merit of new concepts relative to both present systems and to other emerging concepts. System engineers track new concepts that are evolving in the **Conceptual Design and Assessment Program Element** and advance the best of these concepts to the next level of maturity. They also follow developments in materials, electronics, mechanical components, and other areas that are covered by other Program Elements and integrate these emerging technologies and processes into their engineering designs. This integration of advancing technology yields the products and core capabilities needed to meet critical system needs in a timely manner. The ability to constantly introduce emerging technologies into weapon applications has been the key to the Nation's tech-

nological superiority in nuclear weaponry, thus the key to maintaining the vitality of nuclear deterrence.

The boundaries between the responsibilities of **System Engineering Science and Technology** and those of the other Program Elements, as well as between **System Engineering Science and Technology** and work covered by one of the **Defense Programs Initiatives**, are not always well defined. On the one hand, the work done within this Program Element is generally distinguished by an emphasis on the integration of multiple technologies, rather than a focus on a single technology area. The **System Engineering Science and Technology Program Element** addresses significant design goals such as improved safety, security, and use control. It underpins the capability to manufacture needed products, including weapon disassembly, while addressing important quality, cost, performance, and ES&H concerns. On the other hand, a Phase 1 and 2 Study with the military may be started in this Program Element and then move into one of the **Initiatives** as it matures. Alternatively, specific aspects of such a Phase 1 or 2 Study may, depending on their generality, be covered by this Program Element while other aspects are being included within an **Initiative**.

A key component of this evolving Program Element is its work in the area of agile product realization. Products manufactured in the future nuclear weapons complex will reflect an integration of the best of modern manufacturing technology. Today's research and technology development will enable this future capability by advancing concurrent engineering methods; including life cycle

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assessment, the use of environmentally conscious materials and processes, flexible production techniques that are suitable to small lot or low volume operations, advanced communications and data manipulation technologies, and automation and robotic technologies. While underpinning the Defense Programs stockpile stewardship and reconfiguration missions, these efforts also leverage dual benefit applications and contribute to the

Nation's Advanced Manufacturing Technology Initiative.

Many other defense initiatives and missions of the DOE, in addition to Defense Programs, benefit directly from the work covered by this program element. These include the Office of Safeguards and Security and the Office of Intelligence and National Security.

B. Major Activities, Enablers, and Benefits in the Area of System Engineering Science and Technology:

Major Activities		Enablers and Benefits
focal area: SURETY ASSESSMENTS and TECHNOLOGY	Use Control	threat assessments, PAL, protected volume, enhanced denial effectiveness, data bases, data authentication, and secure communication
	Safety	threat assessments, fire-resistant pits, insensitive HE, DOI, PEX, ENDS, PRA, and inherent safety
	Security and Transportation	threat assessments, vaults, assess delay, remote inventory system, GPS, robotic guards, laser imaging and ranging, implantable imager, data compression, data fusion, secure communication, secure and smart containers, and lightweight armor
	Weapon Design Information Security	bilateral treaty monitoring
	Dismantlement	human safety, robotics, environmental protection, and waste management
focal area: EXPLORATORY STUDIES & TECHNOLOGY	Systems Analysis	threat assessments, comparisons of alternative approaches, new mission effectiveness studies, and Phase 1&2 Studies with the military
	Exploratory Components	advanced packaging for high density electronics, compact power sources, explosive components, clocks, high current switches, coded switches, gas transfer components not exposed to Tritium, novel ideas, Focal Point, STEP, and standardization
	Exploratory Systems	penetrators, standoff bombs, navigation, precision guidance, SAR, GPS, global coordinate enable, and data fusion
focal area: ENGINEERING & TESTING INFRASTRUCTURE	Engineering Technology	maintain key skills and facilities and evolve substitute materials and processes for ES&H improvements and cost containment
	Developmental Testing	maintain strategic test capabilities
	NonDestructive Evaluation Technology	radiography, tomography, image processing, & ultrasonic techniques

Major Activities		Enablers and Benefits
focal area: MANUFACTURING TECHNOLOGIES	Agile Manufacturing	rapid prototyping, intelligent machines, modelbased process control, concurrent engineering, robotic assembly and disassembly, and computerized databases
	Advanced Processing	reduction/elimination/substitution of materials and solvents, environmentally conscious manufacturing, modelbased process control, FASTCAST, SMARTWELD, precision turning, stereolithography, precision die casting, and robotic assembly and disassembly

Note:

Enablers and Benefits are, in this context, activities, programs, objectives, or technologies that either enable or benefit or are enabled or benefitted by work in **System Engineering Science and Technology**.

C. Key Challenges and Milestones in the Area of System Engineering Science and Technology:

Key Challenges	Related Initiatives	Major Milestones
A Robust, Standardized, Neutron Generator with a Greatly Extended Lifespan (Sandia National Laboratories)	Stockpile Stewardship	Proof of Concept for a 50 Year Lifespan First Quarter of 1996 Proven Manufacturing Process that Meets Cost Goals First Quarter of 1998
Direct Optical Initiation (DOI) Firing Set (Los Alamos & Sandia National Laboratories)	Stockpile Stewardship	Complete Prototype Design for DOI Architecture First Quarter of 1995 Transfer Proof of Concept Demonstration from the Explosives Program Element First Quarter of 1995 Complete Design Definition and Certification First Quarter of 2000
Transferable, Insensitive, Paste Main Explosive (Lawrence Livermore and Sandia National Laboratories)	Stockpile Stewardship	Transfer Proof of Concept Demonstration from the Explosives Program Element First Quarter of 1996 Complete Design Definition and Certification First Quarter of 2000

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Key Challenges	Related Initiatives	Major Milestones
Integrate Advanced Use Control Architecture into the Nuclear Command & Control (NCC) System and Include Remote Realtime PAL Inventory & Recode (Sandia National Laboratories)	Stockpile Stewardship and Safeguards & Security	Proof of Concept for Two Way Communication Architecture Fourth Quarter of 1993 Complete Design Definition for Two Way Communication Architecture Fourth Quarter of 1994 Design Definition for Integrated NCC/PAL Fourth Quarter of 1996
Fire Resistant Pits (FRP) (Lawrence Livermore and Los Alamos National Laboratories)	Stockpile Stewardship	Proof of Concept Demonstration with Reused Pits Fourth Quarter of 1994 Proof of Concept Demonstration for FRP Containment Temperature Second Quarter of 1995
Automatic Planning & Programming of Intelligent Machines for Agile Manufacturing (Sandia National Laboratories)	Stockpile Stewardship and Reconfiguration	Factory Floor Demonstration First Quarter of 1998
Advanced Command & Control Architecture (Sandia National Laboratories)	Stockpile Stewardship and NonProliferation	Demonstration of Prototype Satellite System First Quarter of 1997
Imaging Radar (Sandia National Laboratories)	Stockpile Stewardship and NonProliferation	Demonstration of Precision Guidance System Fourth Quarter of 1994 Ground Penetration Experiments First Quarter of 1996

Note:

The **Key Challenges** and **Milestones** indicated above are based on the assumption of a "stable" funding profile over the duration of the projects. Significant variations in funding during this period could obviously force reassessment of project goals and schedules.

D. Potential Benefit to DOE Energy Programs:

Benefits to DOE energy programs result in the areas of environmentally and energy conscious manufacturing and materials for fire-resistant pits.

E. Potential Benefit to the Department of Defense

Those areas of this Program Element that are of interest to the DoD include:

- command and control technologies;
- electronic arming and fuzing sets that are cost competitive with traditional technology with improved reliability, safety, and performance;
- affordable manufacturing;
- secure communications;
- automatic programming of intelligent machines and robots;
- secure and safe transportation;
- advanced manufacturing technology, including concurrent engineering and integration of design at various locations using high-speed communication links; and
- design for environmentally conscious manufacturing, dismantlement, and disposal, as required for all DoD munitions acquisitions.

F. Potential Benefit to National Economic Growth:

The benefits to industry are similar to those listed in Section "E" above, specifically including:

- secure communications;
- the automatic programming of intelligent machines and robots;
- secure and safe transportation;
- advanced manufacturing technology, including concurrent engineering and integration of design at various locations using high-speed communication links; and
- environmentally conscious design and manufacturing.

[REDACTED]

[REDACTED]

Electronics, Photonics, Sensors, and Mechanical Components

A. Programmatic Importance to DOE Defense Missions:

Electronic, mechanical, and aerodynamic components largely determine the precision of the delivery of a weapon to the target, the reliability of the system, and the operability of the weapons in the potentially severe environments generated by the defensive measures of the targeted country.

The use of electronics in nuclear weapons is pervasive and involves the extensive use of special-purpose microelectronic circuits. Special-purpose electronic components in nuclear weapons include coded switches that prevent unauthorized use, tamper detectors, programmers that control the arming and firing sequence of the weapon, radars, and the fuzing and firing sets. These devices must operate reliably over a large temperature range, survive strong mechanical shock, and be fully and reliably functional following exposure to the ionizing radiation of space and to the intense pulses of ionizing and electromagnetic radiation caused by nearby nuclear detonations.

Many of the requirements for electronic devices for nuclear weapon applications cannot be met with commercial products. This is also true for many of the mechanical and aerodynamic components. Taken together, these components largely determine the reliability of the weapon after an extended period of time in stockpile, as well as the maintenance requirements of weapons in stockpile. Consequently, innovations in these areas are driven by DOE defense requirements and have had, and will continue to have, important life-cycle cost benefits.

Photonics represents an emerging technology area in which photons are used to execute functions normally performed by electronic devices. Because of the inherent immunity of photonic devices to electromagnetic interference and their tolerance to the effects of ionizing and electromagnetic radiation, photonic devices offer unique advantage over traditional electronic devices for a wide variety of weapon applications.

For example, photonics is the enabling technology for the optical firing set, which is being studied as a possible replacement for the traditional electrical system. This firing set offers greatly enhanced safety in the event that a weapon is exposed to the severe abnormal environments that can be associated with crashes or lightning. It uses a laser and optical fibers rather than the traditional electrical method to trigger the explosive detonators that initiate the nuclear reaction.

Portions of the research and development leading to the optical firing set are also being pursued through the **Explosives and Systems Engineering Science and Technology Program Elements**; however, technologies in **Electronics, Photonics, Sensors, and Mechanical Components**, including compact lasers and optical charging and triggering technology, are all critical to its development.

Sensor research and development supported by this Program Element includes radars for the precision terminal guidance and firing of the weapons, components that detect unauthorized tampering, use-control devices, accelerometers, and chemical sensors to assess the state of health of weapons in stockpile.

The technology base sustained by this Program Element is critical to essentially every defense mission, initiative, and program of the Department. Satellites that monitor compliance of other countries with treaties on weapons of mass destruction require microelectronics devices that are hardened against the ionizing radiation of space. Application-specific microprocessors and embedded computers are needed by many of the systems used to verify treaty compliance and to assess efforts in foreign countries that may indicate research, development, and production of weapons of mass destruction. Also, advanced sensors, such as chemical microsensors, LIDAR, and high-performance synthetic aperture radars developed in this

program element offer new capabilities for arms control and proliferation assessments. These technologies are also critical for the safeguards and security efforts of the DOE. Chemical sensors and LIDAR capabilities have applications for assessment of chemical hazards in nuclear waste sites in support of the Office of Environmental Restoration and Waste Management. Also, many of these capabilities are of primary importance in the Emergency Response program of the DOE. Furthermore, the strengths in electronics, microelectronics, and photonics that are sustained by this Program Element are promoting economic growth through technology transfer to, and collaboration with, the private sector.

B. Major Activities, Enablers, and Benefits in the Area of Electronics, Photonics, Sensors, & Mechanical Components:

Major Activities		Enablers and Benefits
focal area: ELECTRONIC SUBSYSTEMS	Radars	proximity fuzing and firing, precision terminal guidance, and SAR with realtime image formation
	Neutron Generators	increased shelf life, standardization, simplified production, and robust design to increase acceptance rate
	Programmeters	standardization and onboard control of all functions
	Firing Sets	Direct Optical Ignition (DOI), standardization, increased use of commercial parts, and laser diode ignition of thermal batteries
	Electronic Fuzing	standardization and increased use of commercial parts
focal area: ELECTRONIC COMPONENTS	Microelectronics	radiation resistant nonvolatile memories and Application Specific Integrated Circuits (ASICs); ferroelectric memory; advanced processing methods and equipment, including sensor based control; maintenance of the defense industrial base; and promotion of economic growth
	Clocks	small, rugged, low power, precision clocks for microprocessor control
	Switching Tubes	high current, high voltage devices for firing sets
	Power Sources	thermal batteries, lithium batteries, capacitors, and standardization

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Major Activities		Enablers and Benefits
PACKAGING and INTERCONNECTS	Packaging	encapsulation, multichip modules, printed circuit boards, testing and troubleshooting, diamondlike mounting materials
	Interconnection	optical interconnections
RELIABILITY and CERTIFICATION	Failure Analysis	test chips, methodology development, and expert systems
	Certification	radiation hardness and environmental effects
focal area: PHOTONIC MATERIALS	Compound Semiconductors	strained layer superlattices, III-V and II-IV alloys, band gap engineering, diode lasers, IR detector arrays, and optical memories and logic
	Ferroelectric	image storage, waveguides, and nonvolatile memory
	Integrated with Silicon	strained Ge and SiGe intermediate layers
	Processing Equipment	improved materials and online process control
focal area: PHOTONIC DEVICES	Diode Lasers	edge-emitting and vertical cavity surface-emitting diode lasers, high power diode lasers, integration into silicon ICs, power transfer into protected volumes, optical ignition of pyrotechnics, interchip optical connections, and chemical sensing and monitoring
	Solid State Lasers	Direct Optical Ignition (DOI), sources for LIDARs, laser spectroscopy, and control of materials processing equipment
	Nonlinear Optics	wavelength conversion via optical parametric oscillators and amplifiers, optical to optical switching, and sources for control of materials processing equipment
	Modulators and Waveguides	signal processing and SAR applications
	Detectors	IR detector arrays with improved performance over HgCdTe, radiation compensated optically controlled thyristors, and optical to electrical power conversion for firing set usage
focal area: PHOTONIC SUBSYSTEMS	Power Transfer	electrical to optical to electrical power conversion for powering components located within protected volumes
	Communications	intraweapon systems
	Fully Optical Firing Sets	enhanced safety
	Imaging	laser ranging and imaging for physical security applications and acoustic/optic image correlation for automatic target identification
	Signal Processing	optical information and image processing

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Major Activities		Enablers and Benefits
focal area: MECHANICAL COMPONENTS	Stronglinks and Weaklinks	surety components, standardization, cost reduction, micromachining, optical feedthroughs, and low friction coatings
	Paste Explosive Transfer Systems	intrinsic safety and materials compatibility
	Trajectory Sensing Signal Generators	intent enable and standardization
	Acceleration Sensors	rolamite switches and standardization
AERODYNAMIC COMPONENTS	Parachutes	flight crew survival via delay, hypersonic deployment, predictive capability, and active control
	Cases	structural integrity, glide bombs, and crash simulation and testing
focal area: SENSORS	Chemically Selective	process control, environmental control, waste and site characterization, and stockpile aging and degradation monitoring
	Physical	intrusion detection, radiation detection, tamper detection, and tags and seals
	LIDAR	waste and site characterization and proliferation detection and assessment

Notes:

The **Enablers and Benefits** listed above are activities, programs, objectives, or technologies that either enable or benefit or are enabled or benefitted by work in this Program Element.

The **Key Challenges and Milestones** listed below are based on the assumption of a "stable" funding profile over the duration of the projects. Significant variations in funding during this period could obviously force reassessment of project goals and schedules.

C. Key Challenges and Milestones in the Area of Electronics, Photonics, Sensors, & Mechanical Components:

Key Challenges	Related Initiatives	Major Milestones
Miniaturized Solid State Laser for a Direct Optical Initiation (DOI) Firing Set (Sandia National Laboratories)	Stockpile Stewardship	2X Reduction in Size and Certification for Weaponization First Quarter of 1996 5X Reduction in Cost First Quarter of 1997
Ferroelectric Nonvolatile Memory Integrated with CMOS (Sandia National Laboratories)	Stockpile Stewardship and NonProliferation	256 bit DRAM Demonstration Third Quarter of 1993 4 Kbit DRAM Demonstration Second Quarter of 1995

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Key Challenges	Related Initiatives	Major Milestones
Clock Fabrication Using Silicon Micromachining Technology (Sandia National Laboratories)	Stockpile Stewardship and NonProliferation	Demonstration Fourth Quarter of 1993
Plasma Etching Capability for the Next Generation of ICs (Sandia National Laboratories)	Stockpile Stewardship and NonProliferation	0.3 micron Lines and Spaces Second Quarter of 1994 0.1 micron Lines and Spaces Second Quarter of 1997
Optically Controlled Thyristor with Compensated Gate Capable of 250 Volt Switching (Sandia National Laboratories)	Stockpile Stewardship	Complete a Phase 3 Equivalent Demonstration Fourth Quarter of 1993
Broadly Tunable Compact Ultraviolet Source based on Optical Parametric Technology (Sandia National Laboratories)	Site Restoration, Emergency Response, and NonProliferation	Demonstrate Proof of Concept First Quarter of 1994 LIDAR Field Demonstration Second Quarter of 1995
Vertical Cavity Surface-Emitting Diode Laser (Sandia National Laboratories)	Stockpile Stewardship	Diffraction-Limited Demonstration Fourth Quarter of 1993 1Watt Demonstration Second Quarter of 1995
Optical Coherent Image Correlator (Sandia National Laboratories)	Stockpile Stewardship and NonProliferation	Demonstrate Feasibility for Individually Addressable Arrays of Logic Elements Second Quarter of 1997
Predictive Capability for the Inflation of Unsteady Parachutes (Sandia National Laboratories)	Stockpile Stewardship	Complete Second Quarter of 1995
Chemically Selective Sensors (Sandia National Laboratories)	Reconfiguration, Site Restoration, Stockpile Stewardship, and NonProliferation	Demonstrate a 6-Element Array and Advanced Pattern Recognition Capability Second Quarter of 1994 Demonstrate a 20-Element Array and High-Specificity Pattern Recognition Capability Fourth Quarter of 1995
Radiation-Hardened, SONOS-Based, Electronically Erasable, Read-Only Memory with 100 Year Retention (Sandia National Laboratories)	Stockpile Stewardship and NonProliferation	WR Deliveries Fourth Quarter of 1993

D. Potential Benefit to DOE Energy Programs:

The chemical sensor capabilities developed by this Program Element will be applicable to the control of manufacturing equipment and processes, reducing energy consumption, hazardous waste production, and pollution of the environment. LIDAR is applicable to pollution monitoring and control and atmospheric research. Microelectronics components that operate reliably at high temperature will find important applications in automotive control systems, minimizing pollution and maximizing engine efficiency. The direct mounting of electronics on engine blocks will improve reliability by reducing their susceptibility to damage. High temperature electronics for downhole instrumentation in drilling will also reduce costs.

E. Potential Benefit to the Department of Defense

Most of the work in electronics, photonics, and sensors within this Program Element are of interest to the DoD. While many of the mechanical and aerodynamic components covered here are specific to nuclear weapon applications, there is also substantial applicability to conventional weapons. Two such examples are DOE parachute technology, recognized as the most advanced effort in the world; and mechanical acceleration sensors. Other areas of high interest to the DoD include:

- high-speed digital circuits based on GaAs and other compound semiconductors;
 - optical interconnects, memory, and gate arrays for compact, high speed, signal processing with unprecedented radiation hardness and immunity to electromagnetic fields;
 - multi-chip module packaging for ultra-high-density multiple chip integration, including methods to test and troubleshoot;
 - photonic sensor systems using steerable optics, large focal plane arrays, multispectral sensors, and extensive onboard processing and data compression, which will be used to globally monitor, detect, locate, and characterize transient optical events such as nuclear or conventional explosions, missile launches, or lightning;
 - SAR systems using high speed, miniature, ruggedized components for near realtime imagery, inertial measurement, and target recognition, including compensation for phase errors induced by platform motion;
 - sensor and satellite system and subsystem design, fabrication, and testing, including power, command, data handling and processing using massively parallel architectures, attitude determination and control, communications, timing and navigation, and both active and passive control;
 - radiation hardness assurance methodology to assess hardness and develop an understanding of the principles determining hardness and single event upset (SEU) as a means of characterizing and predicting transient and SEU response in ICs;
 - IC reliability assurance capability to ensure high reliability ICs from small production runs and commercial products;
 - embedded massively parallel computing architectures for flight systems that support large format focal plane arrays and SAR systems;
 - compact telemetry systems for communications;
 - target acquisition and damage assessment via unattended ground sensors, in the form of air-dropped battlefield sensors that include magnetic intrusion detection systems, seismic, acoustic, day/night linear array imagers for moving targets, and tags for identification;
- Synthetic Aperture Radar (SAR) with realtime processing capabilities;
 - low cost electronic fuzing;
 - radhard nonvolatile memory and microprocessors, with performance equal to commercial devices, but hardened to operate in ionizing radiation and applicable to strategic and tactical systems, satellites, and read only memory (ROM) with 100-year retention capability;
 - high-frequency power devices for radars and communications using 60 GHz (eventually 94 and 144 GHz) GaAs power devices;

- micro analytical instruments and environmental sensors in the form of compact, low-power devices that can monitor and identify chemicals for the purposes of monitoring the degradation of explosives, process control in manufacturing, verification of treaties, and the assessment of activities associated with development of weapons of mass destruction;
- far infrared sensors, having high sensitivity in the 10 to 16 μm range, can replace HgCdTe systems and offer improved lifespans, reduced costs, and extended wavelength ranges;
- low voltage, radhard nonvolatile memories, based on ferroelectric capacitors and offering exceptionally high endurance, write speeds, retention time, radiation tolerances, and immunity to single event upset;
- semiconductor diode lasers for integrated high speed interchip connections, optical computing, and high-resolution displays; and
- semiconductor processing equipment and control methods for the fabrication of ultra-high-density ICs with intelligent processing systems that are adapted to low cost, reliable, low volume production runs and include process modeling, sensor-based processing, control instrumentation, contamination reduction, and advanced lithography capabilities.

F. Potential Benefit to National Economic Growth:

In gross sales, electronics is the world's largest manufacturing industry, employing more than two million Americans. Both national defense and national economic security are critically dependent on the qualitative superiority of the domestic electronics industrial base. The Nation has lost leadership in many areas of electronics and our domestic industrial base is threatened as a result. The activities sustained by this Program Element have made substantial contributions to the Nation in this critical field and the Defense Programs National Laboratories continue to have some of the finest capabilities in the world in many areas that can

and will influence the future of this industry. Areas of strength, within these Laboratories, include knowledge of the underlying physics of the devices and the materials used to make them, failure analysis and quality assurance technology, and device manufacturing equipment development and control. If properly accessed and applied, these strengths can and will have lasting positive effects on the domestic electronics industry. Specific areas of interest include:

- the modeling and simulation of processes used in the manufacturing of modern microelectronics devices and the use of model results to both improve equipment capabilities and implement active process control for improved yield and flexible adaptation to new requirements;
- a theoretical understanding of the underlying physics of microelectronics devices and its use in scientifically designing devices with unprecedented capabilities;
- ultra-high-density packaging of multiple chips to improve speed and obtain intrinsic capabilities to test and troubleshoot performance;
- three dimensional optical interconnects for the integration of multichip modules;
- low voltage, radhard, nonvolatile memories based on ferroelectric capacitors, which offer the potential for exceptionally high write speed, long retention time, high radiation tolerance, and high immunity to single event upset;
- semiconductor diode lasers for high speed interchip connections, optical computing, and high-resolution displays;
- IC reliability assurance capabilities that ensure high reliability ICs from small production runs;
- high power diode lasers;
- high average power solid state lasers and widely tunable, efficient wavelength converters; and
- a state of the art microelectronics production research line that is being made available to domestic industrial partners for the testing of new production equipment.

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RESEARCH AND TECHNOLOGY DEVELOPMENT

Chemistry and Materials

A. Programmatic Importance to DOE Defense Missions:

Meeting the demanding reliability, safety, and physical security requirements of nuclear weapons requires a diverse range of materials expertise and capabilities, many of which are unique to the Defense Programs National Laboratories. Nuclear weapons must operate reliably in severe environments characterized by strong mechanical shock, intense electromagnetic fields and ionizing radiation, and large temperature excursions. Also, they must not detonate or disperse nuclear materials in response to accidental exposure to severe abnormal environments characterized by fire, mechanical shock, electrical shock, static charge, electromagnetic fields, or combinations of these conditions. At the same time, the requirement for extremely high reliability must be met by weapons that have been in storage for several decades with little or no maintenance or testing. In the future, it will be necessary to certify reliability without full-scale testing. The activities supported by this Program Element are critical to meeting these requirements.

This Program Element also maintains the infrastructure needed to assess materials-related deficiencies as they are uncovered in weapons in the stockpile. Because of the unique nature of many weapon components, such troubleshooting and failure analysis requires special expertise and unique capabilities.

Meeting the materials development and analysis requirements for nuclear weapons engineering and stockpile support requires broad capabilities in

materials characterization, materials science theory, modeling and simulation, and synthesis and processing. This knowledge must span a wide range of materials; including metals, ceramics, glasses, organics, composites, and semiconductors (semiconductor materials are covered in the Electronics, Photonics, Sensors, and Mechanical Components Plan).

Current activities focus on alternative materials and processes that can reduce the cost of both the production and eventual demilitarization of parts and components, as well as realizing longer life components, reducing the required maintenance of weapons in stockpile, reducing concerns of possible harmful effects on the environmental, and realizing the highest practical safety in the workplace. These capabilities in materials technologies are fundamental to an evolving agile product realization process that will be the trademark of the reconfigured production complex.

The technologies and facilities infrastructure sustained by this Program Element also directly benefits defense projects of the DOE that fall outside of the direct responsibility of the Assistant Secretary of Defense Programs. Projects under the direction of the Office of Environmental Restoration and Waste Management and projects supporting Safeguards and Security, as well as the **Stockpile Stewardship Initiative**, are direct beneficiaries. These efforts need special purpose materials and processes and rely heavily on the materials characterization capabilities that are sustained by this Program Element.

DEFENSE PROGRAMS **RESEARCH and TECHNOLOGY DEVELOPMENT**

B. Major Activities, Enablers, and Benefits in the Area of Chemistry and Materials:

Major Activities		Enablers and Benefits
focal area: SYNTHESIS/PROCESSING of METALS	Welding, Brazing, and Bonding	firing sets, stronglinks, cases, pressure vessels, gas transfer systems, and SMARTWELD
	Soldering	firing sets, radars, fluxless soldering, and leadfree soldering
	Melting and Casting	firing set housings, palladium and palladium alloys, refractory alloys, and FASTCAST
	Thermal and Mechanical Processes	rapid solidification, hydrogen getters, cases, and pressure vessels
	Surface Modification, Coating, and Cleaning	ion implantation for increased wear and corrosion resistance; electrodeposition; chemical and physical vapor deposition, including plasma enhanced deposition; plasma etching; solvent substitution; epitaxy; and multilayer, thin film for flyer plates
SYNTHESIS/PROCESSING of CERAMICS and GLASSES	Glasses	actuators, connectors, optical fibers, spin-on glass, glass to metal seals, sol gel, detonator headers, and solder glasses for electronics
	Powders	superconductors, piezoelectrics, and sintering
	Solutions	microporous materials and ferroelectrics
	Surface Modification and Coating	diamond and diamondlike coatings, Si_3N_4 and cubic BN thin films, silicon carbide, <i>in situ</i> barrier layers, plasma cleaning and etching, CVD, ion implantation, and thin film varistors
focal area: SYNTHESIS/PROCESSING of ORGANICS	Organic Materials	fullerenes, adhesives, and substitutes for chlorinated solvents
	Polymers and Elastomers	encapsulants, polymer alloys, batteries, and less toxic and noncarcinogenic substitute materials
	Foams, Films, and Membranes	microcellular foams, chemically selective coatings, shipping container fillers, amorphous carbon films, and membranes for the separation/removal of chemicals from waste streams
	Surface Modification and Coating	nonlinear optical materials, optical coatings, metalization, and plasma deposition and cleaning
	Energetic Materials (Explosives Program Element)	primary explosives, detonators, actuators, explosive bolts, flux compression power sources, pyrotechnics for thermal batteries, and polymerized high explosives
focal area: SYNTHESIS/PROCESSING of COMPOSITES	Fiber Reinforced Composites	smart materials, chemical vapor infiltration, metal infiltration, diamondlike fibers, and composites using polymer, metal, and ceramic matrices
	Adhesives	firing sets
	Laminates	smart materials and laminate foils for pulsed power components
	Seals	actuators, connectors, and headers for detonators
	Packaging Materials	smart materials

DEFENSE PROGRAMS RESEARCH and TECHNOLOGY DEVELOPMENT

Major Activities		Enablers and Benefits
SYNTHESIS & PROCESSING of SEMICONDUCTORS	Semiconductors (Electronics, Photonics, Sensors, & Mechanical Components)	silicon and compound semiconductors; microprocessors and memories; light emitting diodes and diode lasers; optical detectors, memories, and processors; chemical sensors; epitaxy, including MBE; CVD; plasma etching; lithography; and micromachining
	Chemical	thermochemical and kinetic properties, materials compatibility relationships, tritium reactivity, surface chemistry, and corrosion susceptibility
CHARACTERIZATION of MATERIALS PROPERTIES	Physical	thermodynamic, electronic, electro-optical, and optical properties; EOS and constitutive relations; thermal stability; surface diffusion and defects; and friction and adhesion
	Corrosion	detonators, cases, and the fundamental theory of corrosion processes
focal area: CHARACTERIZATION of MATERIALS PERFORMANCE	Aging and Compatibility	firing sets, neutron generators, tritium containers and transfer components, pit reuse, and FRP certification
	Deformation, Fracture, & Durability	tribology, stress corrosion cracking, and fracture toughness
	Failure Analysis	stockpile surveillance and troubleshooting
	Hydrogen Effects	embrittlement, tritium microstructure effects, and tritium effects on the integrity of welded joints
	Radiation Effects	radiochemistry, SEU and accumulated dose degradation of electronic memories and microprocessors, stimulated desorption induced EMP, and optical firing sets and fibers
	Electronic, Magnetic, & Optical Behavior	superconductors, piezoelectrics, ferroelectrics, and optical fibers
	Bulk	chemometrics, phase relationships, laser spectroscopy, and x-ray, ion beam, neutron diffraction
CHARACTERIZATION of STRUCTURE and COMPOSITION	Interfaces	adhesion and friction, atomic force and scanning tunneling microscopy, and advanced ion beam analysis
	Microstructure	helium bubbles, polycrystalline plasticity, and evolution during forming
	Defects and Carriers	compound semiconductors, ferroelectrics, and joints
	Performance Prediction	constitutive relationships, aging predictions, solder joint life prediction, and hydrogen effects
focal area: THEORY, MODELING, and SIMULATION	Process Modeling	CVD, plasma etching, FASTCAST, SMARTWELD, forming, heat treating, and intelligent manufacturing
	Structure & Composition Prediction	polycrystalline plasticity, microstructural evolution, texture predictions, electronic bonding, alloying effects, glass ceramics, tritium effects, and interfacial physics and adhesion/bonding

DEFENSE PROGRAMS RESEARCH and TECHNOLOGY DEVELOPMENT

Notes:

The **Enablers** and **Benefits** listed on the previous pages are activities, programs, objectives, or technologies that either enable or benefit or are enabled or benefitted by work in **Chemistry and Materials**.

The **Key Challenges** and **Milestones** listed below are based on the assumption of a "stable" funding profile over the duration of the projects. Significant variations in funding during this period could obviously force reassessment of project goals and schedules.

C. Key Challenges and Milestones in the Area of Chemistry and Materials:

Key Challenges	Related Initiatives	Major Milestones
Diamondlike Coatings and Materials for Protected Volume and Electronic Thermal Management Applications (Sandia National Laboratories)	Stockpile Stewardship and NonProliferation	Acceptable Mechanical Properties for Protected Volume Applications Fourth Quarter of 1994 Acceptable Cost for Use in Thermal Management Applications First Quarter of 1995 Acceptable Cost for Use in Simple Geometry Protected Volume Applications First Quarter of 1996 Capability to Coat Complex Protected Volume Surfaces Second Quarter of 1997
Defectfree Ferroelectric Materials for Radhard Nonvolatile Memories (Sandia National Laboratories)	Stockpile Stewardship and NonProliferation	Process Certification Second Quarter of 1995
Environmentally Conscious Replacements for Methylenedianiline (MDA) and Toluene Di-Isocyanate (TDI) Curing Agents (Sandia National Laboratories)	Stockpile Stewardship and Reconfiguration	Eliminate the Use of MDA and TDI within the Nuclear Weapons Production Complex First Quarter of 1995
Leadfree and Fluxless Soldering Capabilities for All Weapons Components (Sandia National Laboratories)	Stockpile Stewardship and Reconfiguration	Certified Capability First Quarter of 1996
Expand the SMARTWELD Toolkit to Reduce Required Time for the Development of Welding Protocols and CAD/CAM Integration (Sandia National Laboratories)	Stockpile Stewardship and Reconfiguration	10X Enhancement Second Quarter of 1994 100X Enhancement Second Quarter of 1995

DEFENSE PROGRAM RESEARCH AND TECHNOLOGY DEVELOPMENT

Key Challenges	Related Initiatives	Major Milestones
Demonstrate the Feasibility of Accelerator Transmutation of Mixed Waste and Spent Fuel (Los Alamos National Laboratory)	Reconfiguration and Nuclear Waste Management	Proof of Concept Demonstration Fourth Quarter of 1994
Acceptable Cost for Composites that Use Diamondlike Carbon Fibers for High Strength and Thermal Management (Los Alamos & Sandia National Laboratories)	Stockpile Stewardship and NonProliferation	Proof of Concept Demonstration Fourth Quarter of 1995 Demonstrate Feasible Production Process Fourth Quarter of 1997
FRP Test Facility (Los Alamos National Laboratory)	Stockpile Stewardship	Operational Fourth Quarter of 1995
Onsite Customized Pit Fabrication Capability (Los Alamos National Laboratory)	Stockpile Stewardship and Reconfiguration	Operational Fourth Quarter of 1996
Onsite Beryllium Machining Capability (Los Alamos National Laboratory)	Stockpile Stewardship and Reconfiguration	Operational Fourth Quarter of 1997

D. Potential Benefit to DOE Energy Programs:

Energy and environment projects supported by the Office of Energy Research (ER) rely heavily on the core materials capabilities that are developed and maintained by work within this Program Element. Areas of particular value to ER include:

- lightweight materials for transportation systems;
- high temperature superconductors;
- high temperature ceramics for high efficiency motor vehicle engines;
- composite materials;
- diamondlike carbon films and substrates for thermal management and durable corrosion-resistant coatings;
- thin film materials and processes for durable and corrosion-resistant coatings;
- joining technology;

- environmentally conscious manufacturing technology;
- energy conserving manufacturing technology; and
- low friction coatings.

E. Potential Benefit to the Department of Defense

Essentially all of the materials and processes developed for nuclear weapon applications have potential application in DoD systems and the defense industrial base. Areas of special importance to the DoD include:

- defectfree ferroelectric materials for nonvolatile microelectronic memories;
- diamond or diamondlike materials and coatings for thermal management of microelectronic

devices and for enhanced resistance to wear or corrosion;

- substitute materials and materials processes that reduce production cost, including cost associated with ES&H concerns;
- composite materials of all types;
- smart materials, which adjust to physical stimuli to improve performance or correct or highlight defects that develop during use;
- methods to reduce the time needed to design new investment castings (FASTCAST);
- methods to reduce the time required to develop welding schedules (SMARTWELD);
- encapsulants that have low coefficients of thermal expansion and thereby reduce stresses on packaged products;
- coatings or other surface modification methods that reduce friction and/or wear;
- coatings or other surface modification methods that increase resistance to corrosion; and
- adhesives that have higher bond strength and good performance over larger temperature and thermal cycle ranges.

F. Potential Benefit to National Economic Growth:

Essentially all of the materials and processes developed for defense applications eventually find commercial applications, thus promoting economic growth and strengthening the domestic industrial base. Areas that are of particular current importance in this regard, in addition to those already mentioned in Section "E" above, include:

- computer design of molecules, materials, and processes;
- methods to predict the properties of new materials in the early phases of synthesis and process development; and
- methods to reduce the development and product introduction times for new materials.

Special Nuclear Materials

A. Programmatic Importance to DOE Defense Missions:

Special Nuclear Materials (SNM) are currently defined as Plutonium, Uranium, and Lithium Salt, although other SNM materials may be added as nuclear explosives designs evolve. These materials are essential to the production and maintenance of nuclear weapons. Since they are chemically very reactive and most are highly radioactive, the handling and processing of SNM requires specialized technical expertise and costly facilities and the United States' capabilities in these areas, including essential expertise in manufacturing, purification, recycling, and waste management; reside principally within the Department of Energy's Nuclear Weapons Complex. In fact, many of these specialized capabilities and facilities exist, within the United States, only within the Department of Energy's Defense Programs National Laboratories.

Unique aspects of SNM technology include the processing and use of these materials with full regard for worker and environmental safety and health, cost control, nuclear material and waste management considerations, accurate materials accountability, and safeguards and security. The **SNM Program Element** supports the research and development and infrastructure needed to evolve and maintain this technology.

Treaty agreements, changing stockpile policies, and tighter environmental safety and health regulations are shifting the priorities of the **SNM Program Element**. In addition to the need for better ways to manage the nuclear and mixed waste generated by SNM processing activities, the accelerated retirement of weapons from stockpile is adding new requirements and a new urgency. For example, to meet more stringent environmental safety and health requirements, nuclear and mixed waste streams and the exposure of workers to radiation must all be reduced and current policy on SNM reuse is forcing the development of a better understanding of the aging and longterm chemistry and metallurgy of these materials. Emphasis is currently being placed on recycle procedures, precision casting, dry machining, robotic handling of SNM, and improved treatment of hazardous byproducts and wastes.

The expertise that is evolved and sustained by this Program Element is essential for weapons research, development, and testing; emergency response; Reconfiguration; Stockpile Stewardship; environmental restoration and waste management; treaty verification; and NonProliferation. In one form or another, the **SNM Program Element** provides critical support to virtually all of the defense missions of the DOE, including those which fall outside of the direct responsibility of the Assistant Secretary of Defense Programs.

B. Major Activities, Enablers, and Benefits in the Area of Special Nuclear Materials:

Major Activities		Enablers and Benefits
focal area: PLUTONIUM PROCESSING	Flow-Sheet Modeling	operational parameters that minimize waste, increase flexibility, and reduce both cost and worker exposure
	Manufacturing	casting, including precision die casting; machining, including dry machining; welding; prototyping; and waste minimization
	Purification	waste minimization
	Residue Treatment	recovery of Pu from mixed residues and destruction of organic constituents
	Analytical Technologies	SNM inventory accountability, quality assurance, and improved understanding of processes
PLUTONIUM STOCKPILE MANAGEMENT	Surveillance and Maintenance	evaluate the condition of pits currently in the stockpile, evaluate their potential for reuse, and develop new NDT technologies
	Dismantlement	ES&H and disassembly procedures
	Aging and Reuse	assess acceptability of pit reuse without reprocessing
PLUTONIUM RESEARCH & FACILITIES	Surety Research	retard accidental dispersal of Pu and develop FRP encasements
	Basic Research	corrosion, helium bubble formation and effects, EOS, and microstructural changes with aging
	Facilities	maintenance of capabilities to avoid technological surprise
focal area: URANIUM PROCESSING	Flow-Sheet Modeling	operational parameters that minimize waste, increase flexibility, and reduce both cost and worker exposure
	Manufacturing	hot worked wrought parts, waste reduction, recycling of scrap, alloy substitution, and casting, including net shape casting
	Purification and Residue Treatment	recycling of scrap and oxide to metal conversion
	Analytical Chemistry	process control and quality assurance
	Material Control/Accountability	improved accuracy of control and accountability
URANIUM SUPPORTING ACTIVITIES	Surveillance and Maintenance	maintain database of stockpile issues, strategies, and solutions
	Research and Development	chemical properties database and advanced manufacturing technologies
	Facilities	maintain a comprehensive set of processing capabilities

Major Activities		Enablers and Benefits
focal area: SALT MATERIALS PROCESSING	Flow-Sheet Modeling	operational parameters that minimize waste, increase flexibility, and reduce both cost and worker exposure
	Electrolysis of LiCl_2	research and development pursuing a reduction in worker exposure to lithium metal
	Recovery of Lithium and Deuterium	process simplification
	Casting	near net shape casting

Notes:

The **Enablers and Benefits** listed above are activities, programs, objectives, or technologies that either enable or benefit or are enabled or benefitted by work in this Program Element.

The **Key Challenges and Milestones** listed below are based on the assumption of a "stable" funding profile over the duration of the projects. Significant variations in funding during this period could obviously force reassessment of project goals and schedules.

C. Key Challenges and Milestones in the Area of Special Nuclear Materials:

Key Challenges	Related Initiatives	Major Milestones
Precision Gravity Casting Process for Plutonium (Los Alamos National Laboratory)	Stockpile Stewardship and Reconfiguration	Completed Fullscale Demonstration and Associated Documentation Fourth Quarter of 1993
Recovery of Plutonium from Mixed Residues and Destruction of Organics (Los Alamos National Laboratory)	Stockpile Stewardship and Reconfiguration	Productionscale Demonstration Fourth Quarter of 1994 Design Definition of Productionscale System Fourth Quarter of 1995
Calorimeter for Determining the SNM Content of Pits (Los Alamos National Laboratory)	Reconfiguration	Complete Fourth Quarter of 1993
Precision Investment Casting of SNM (Lawrence Livermore National Laboratory)	Stockpile Stewardship and Reconfiguration	Benchmark Three Dimensional Moldfilling and Solidification Code Fourth Quarter of 1993
Near Net Shape Casting of Uranium (Los Alamos National Laboratory)	Stockpile Stewardship and Reconfiguration	Process Demonstration First Quarter of 1996

Key Challenges	Related Initiatives	Major Milestones
Uranium Chemical Recovery and Residue Elimination (Los Alamos National Laboratory)	Stockpile Stewardship and Reconfiguration	Process Demonstration First Quarter of 1997
Direct Casting of Uranium Alloys (Los Alamos National Laboratory)	Stockpile Stewardship and Reconfiguration	Process Demonstration First Quarter of 1996
Research and Development Line for Salt Fabrication (Los Alamos National Laboratory)	Stockpile Stewardship and Reconfiguration	Process Demonstration First Quarter of 1998

D. Potential Benefit to DOE Energy Programs:

Many of the capabilities developed through this Program Element are directly applicable to nuclear energy generation. For example, pyroprocessing techniques can be applied to reprocessing fuel for nuclear power plants and an improved understanding of actinide properties and techniques for handling these materials may be of particular longterm benefit to the base technologies that support the energy programs. Precision, waste free, metal-forming technology is relevant to many applications involving hazardous, but nonnuclear, materials and mixed waste treatment processes can also be applied to nonnuclear waste problems.

E. Potential Benefit to the Department of Defense

Many of these capabilities are applicable to nuclear submarines and to military applications for plutonium power sources. Precision metal die casting and precision machining is also of importance to the military.

F. Potential Benefit to National Economic Growth:

Plutonium-238 has applications in power sources, pacemakers, spacecraft, nondestructive testing, and smoke detectors. Areas of special importance to the national economy include:

- special isotopes for power sources, safety devices, nondestructive testing, and medical technology;
- the application of fabrication and waste reduction technologies to nonnuclear hazardous materials;
- mixed waste processing technologies that can be applied to commercial uses of radioactive materials; and
- materials and processing technologies that are applicable to the evolution of commercial nuclear power.

Tritium

A. Programmatic Importance to DOE Defense Missions:

Tritium is essential to modern nuclear weapons. Together with deuterium, it "boosts" the nuclear yield, thus reducing the required amounts of fissile material. It is used in neutron generator tubes, which supply neutrons to enable the initiation of the nuclear explosive, and lithium tritide salts are used as diagnostic materials in nuclear testing.

Tritium is radioactive with a half life of roughly twelve years. This decay process depletes the amount of tritium in the weapon gas systems and neutron tube targets and produces helium-3, which has a high cross section for neutron capture. These two effects combine to degrade the performance of both the neutron tube and the nuclear explosion and together set a limit on the stockpile lives of both gas systems and neutron tubes. Tritium use is complicated by its high chemical reactivity, as well as by the degradation of reservoir materials due to embrittlement and changes in microstructure that are caused by the accumulation of helium. Environmental safety and health issues also complicate the handling of tritium.

Since tritium must be regularly replenished and neutron tubes have a limited lifetime, tritium production and handling technology must be maintained for as long as the nuclear deterrent is

sustained, or until a major change in weapon design eradicates the need for this material. The United States' expertise in tritium production and safe handling and the eventual retirement of tritium contaminated materials resides primarily within the Department of Energy's Defense Programs National Laboratories and the maintenance of these capabilities is primarily the responsibility of the **Tritium Program Element**.

The **Tritium Program Element** addresses all of the core technology associated with tritium use in nuclear weapons. These capabilities include technologies associated with production, safe handling, transportation, tritium and deuterium storage, and the associated gas transfer systems, including valves, actuators, and piping. Fundamental and applied research on materials degradation under exposure to hydrogen, tritium, or deuterium is, however, supported within the **Chemistry and Materials Program Element**. Research on robust new designs of neutron generators and *in situ* tritium and helium-3 management is being pursued as a means of greatly increasing the lifetimes of these components, thus providing safety advantages and cost savings to the military.

Since the production or handling of tritium may indicate nuclear weapon proliferation activities, the expertise within this Program Element is also a valuable resource for nonproliferation and arms control activities.

TRITIUM PROGRAM MANAGEMENT and TECHNOLOGY DEVELOPMENT

B. Major Activities, Enablers, and Benefits in the Area of Tritium:

Major Activities		Enablers and Benefits
focal area: GAS TRANSFER SYSTEMS	Equilibrium Bottles	weld integrity, actuators, tritium reclamation, inspection, microstructural changes, tritium induced cracking, in situ segregation of helium-3, and maintenance of commercial sources
	Solid Storage	weld integrity, effects of temperature cycling, understanding tritide aging processes, rapid measurement of isotope ratios, reduced maintenance, and reduced tritium production requirements
	Tritium Transfer Systems	firesafe valves, actuators, containers, reduced certification costs, materials compatibility, and increased service life
	NTS Support	gas fills, diagnostic targets, and salt production
NEUTRON GENERATOR TUBES	Supplier Base	maintain tritium supply sources and target charging capabilities
OPERATIONS and PROCESSING	Decontamination and Decommissioning	site restoration
	Process Improvement	tritium recovery, shipping containers, and sensitive monitors
	Waste Minimization	tritiated waste processing technologies

Notes:

The **Enablers and Benefits** listed above are activities, programs, objectives, or technologies that either enable or benefit or are enabled or benefitted by work in this Program Element.

The **Key Challenges** and **Milestones** listed below are based on the assumption of a "stable" funding profile over the duration of the projects. Significant variations in funding during this period could obviously force reassessment of project goals and schedules.

C. Key Challenges and Milestones in the Area of Tritium:

Key Challenges	Related Initiatives	Major Milestones
Ion Beam Tritium Production Capability (Los Alamos & Sandia National Laboratories)	Stockpile Stewardship and Reconfiguration	Proof of Concept Demonstration First Quarter of 1995
Fire Safe Valve (Los Alamos & Sandia National Laboratories)	Stockpile Stewardship	Certified for Stockpile Retrofit First Quarter of 1996

D. Potential Benefit to DOE Energy Programs:

Department of Energy Defense Programs is the principal national source for tritium expertise. Potential energy applications for tritium include magnetic fusion and inertial confinement fusion. The expertise developed and maintained by the nuclear weapon program is critical to these programs in the areas of production, purification, safe handling, materials compatibility, transfer, ICF target materials and filling, magnetic confinement fusion, and decontamination.

E. Potential Benefit to the Department of Defense

Increased lifetime tritium storage containers and neutron generators will reduce both the hazards of stockpile maintenance and cost of maintenance of weapons in the stockpile.

F. Potential Benefit to National Economic Growth:

Potential commercial products that use tritium include brighter, reduced maintenance, emergency lights and power sources.

RESEARCH AND TECHNOLOGY DEVELOPMENT

Explosives

A. Programmatic Importance to DOE Defense Missions:

Explosives play a major role in the performance and safety of a nuclear weapon. They are used to trigger the nuclear explosion and for a myriad of functions that enable the performance of the entire system. These functions include explosive bolts and valves, line charges for missile stage separation, flux compression power sources, propellant igniters, pyrotechnic materials in thermal batteries, and detonators that initiate the energetic materials in these devices. The energy content of these explosives influences both the amount of special nuclear materials required to achieve the intended explosive yield and the overall weight of the system. Safety is largely determined by the response of the explosives in the nuclear assembly and in other weapon components to fire, projectile attack, sympathetic detonation, and a large number of single, combined, and synergistic hazards. The response of the explosive to such nonintended stimuli largely determines the potential for nuclear yield, significant release or dispersal of fissile material, conventional explosive reaction, or virtually no reaction. Because of the severe consequences of unintentional nuclear detonations through handling accidents or other mishaps, the DOE has pioneered the development of explosives that offer enhanced safety.

There is great potential and great need to improve the performance and safety of explosives and associated components. An understanding of localized mechanical and thermal energy buildup and dissipation processes, for all kinds of abnormal stimuli, is essential to achieving an optimal balance

between safety and performance. Achieving this goal involves balancing factors related to availability and cost, dynamic and mechanical properties, chemical and thermal stability, initiation sensitivity, safety, environmental health, and issues, including recycle and disposal, associated with the inevitable retirement of explosive parts. From these studies emerge safer, high energy, explosives offering improved performance.

Activities in this Program Element range from the fundamental physics and chemistry of explosive materials to the engineering of explosive component prototypes and their evaluation for weapons use, maintaining a constant focus on the eventual retirement of the system and disposal of the materials. Current areas of emphasis include firing systems that offer enhanced safety, such as Direct Optical Initiation (DOI) firing sets, and concepts that keep the explosive materials physically separated from the nuclear assembly prior to use authorization.

The technologies and facilities sustained by this Program Element are of direct benefit to many defense missions that fall outside of the direct responsibility of the Assistant Secretary of Defense Programs. The Office of Environmental Restoration and Waste Management takes advantage of explosives characterization and demilitarization expertise in the environmental restoration of sites contaminated by explosives and their byproducts. The Safeguards and Security Program utilizes explosives data and models to assess the vulnerability and design of transportation systems and containers. The Stockpile Support Program benefits from explosives that have longer lifetimes, as well as lower production and disposal costs.

B. Major Activities, Enablers, and Benefits in the Area of Explosives:

Major Activities		Enablers and Benefits
focal area: SYNTHESIS and FORMULATION	New Explosives and Blends	energetic polymers; insensitive, high energy density, high explosives; supersafe high explosives; insensitive paste high explosives; insensitive, extrudable, cast high explosives; high density, low modulus, binders; thermally stable, longer lifetime, photosensitized high explosives; and environmentally acceptable materials and byproducts
	New Binders	energetic binders and latex binders
	Process Substitution	large volume manufacturing, lower cost, and reduction of environmental impacts
	Modeling and Predictability	engineered materials, predictable performance and safety, predictable manufacturing processes, and correlation of static and dynamic properties with molecular structure
MATERIALS CHARACTERIZATION	Static Properties	toxicological properties, molecular structure, chemical stability, paste compatibility with materials data, physical stability, and structural/mechanical properties
	Dynamic Properties	initiation data, including optical initiation data; sensitivity to physical stimuli; and EOS
focal area: THEORY and MODELING	Molecular Properties	molecular properties at extreme temperatures and molecular structure calculations to support the selection of substitute materials
	Physical and Chemical Properties	realistic chemistry, crystal densities, heats of formation, elastic constants, and "cookoff" effects
	Initiation Models	shock and shear initiation, ignition and grain burning, and DDT
	Generic Safety Assessments	predictive capability for all plausible abnormal environments
COMPONENT DESIGN and ASSESSMENT	Initiators and Detonators	supersafe detonators, diode laser ignition, Direct Optical Initiation (DOI), and slapper detonators
	Intrinsic Safety	paste extrudable explosives, and insensitive, extrudable cast, explosives
	Modeling	device specific safety assessments
	Materials Substitution	longer lifetimes, increased safety, ease of disposal, and environmentally benign production and disposal
STOCKPILE SURVEILLANCE	Compatibility Testing	characterization of aged HE and pyrotechnics
	Monitoring	monitoring and evaluating the effects of stockpile environments on explosives and ordnance

RESEARCH and TECHNOLOGY DEVELOPMENT

Major Activities		Enablers and Benefits
focal area: SYSTEM LEVEL SAFETY ANALYSIS	Predictive Models	multi-point safety analysis, SNM dispersal in accidents, and warhead safety assessments
	Environmental Safety and Health Stewardship of the Nuclear Weapons Complex	monitoring of emissions, site restoration, and conduct of operations
focal area: ES&H and DEMILITARIZATION	Demilitarization	reuse, supercritical water oxidation, molten salts, and robotic dismantlement
	Environmentally Acceptable Materials	reduced environmental risks and costs

Notes:

The **Enablers and Benefits** listed above are activities, programs, objectives, or technologies that either enable or benefit or are enabled or benefitted by work in this Program Element.

The **Key Challenges** and **Milestones** listed below are based on the assumption of a "stable" funding profile over the duration of the projects. Significant variations in funding during this period could obviously force reassessment of project goals and schedules.

C. Key Challenges and Milestones in the Area of Explosives:

Key Challenges	Related Initiatives	Major Milestones
Direct Optical Initiation (DOI) Firing Sets (Los Alamos & Sandia National Laboratories)	Stockpile Stewardship	Prototype Demonstration Second Quarter of 1995
Laser Diode Ignition (LDI) of Pyrotechnics (Sandia National Laboratories)	Stockpile Stewardship	Certified for Stockpile Retrofits First Quarter of 1996
Paste Explosive System for Nuclear Initiation (Lawrence Livermore and Sandia National Laboratories)	Stockpile Stewardship	Certified for Selected Stockpile Retrofits First Quarter of 1995 Certified for Main Charge Functions First Quarter of 1996

RESEARCH AND TECHNOLOGY DEVELOPMENT

Key Challenges	Related Initiatives	Major Milestones
Energetic Polymers for High Energy and Improved Safety (Los Alamos National Laboratory)	Stockpile Stewardship and Reconfiguration	Proof of Concept Demonstration Third Quarter of 1993 Certification for Use First Quarter of 1995
Latex Binders for Waste Minimization (Los Alamos National Laboratory)	Stockpile Stewardship and Reconfiguration	Proof of Concept Demonstration Second Quarter of 1994 Certification for Use Second Quarter of 1995
Transferrable Cast IHE for Main Charge (Lawrence Livermore and Sandia National Laboratories)	Stockpile Stewardship	Proof of Concept Demonstration Third Quarter of 1994 Certification for Use First Quarter of 1995 Fullscale Demonstration First Quarter of 1996 Implementation in the Stockpile First Quarter of 2003
IHE with Energy Density Comparable to HMX (Lawrence Livermore and Los Alamos National Laboratories)	Stockpile Stewardship	Identification First Quarter of 1995 Certification for Performance First Quarter of 1996 Manufacturing Process Defined First Quarter of 1998 Manufacturing Capabilities First Quarter of 2000
Predictive Models for High Explosive Performance (All Three DP National Laboratories)	Stockpile Stewardship	Three Dimensional Multiple Shock Reactive HE Burn Model Fourth Quarter of 1993 Complete Validation of TIGER EOS Database Fourth Quarter of 1994 Predictive Capability for XDT/SDT/DDT Fourth Quarter of 1995 Coupled Thermal/Mechanical Chemistry Predictive Capability to Assess Behavior in all Credible Accident Scenarios First Quarter of 1996
Retirement and Disposal Technologies (All Three DP National Laboratories)	Stockpile Stewardship, Waste Management, and Reconfiguration	Proof of Concept Demonstration First Quarter of 1995 Commission Pilot Plant for Reuse/Disposal Capability First Quarter of 1997

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Key Challenges	Related Initiatives	Major Milestones
Composite Explosives (Lawrence Livermore and Sandia National Laboratories)	Stockpile Stewardship	Formulation of HE with Desired Properties for Nuclear Weapons Applications Fourth Quarter of 1996 Commission Pilot Plant for Production First Quarter of 1996
Advanced Diagnostic Capabilities for the Characterization of Energetic Materials (All Three DP National Laboratories)	Stockpile Stewardship	Measure Key Intermediate Species during XDT/SDT/DDT for Code Validation First Quarter of 1996 Femtosecond Resolution Characterization Capabilities for Benchmarking Predictive Codes First Quarter of 1997
Environmentally Conscious Manufacturing of New Energetic Materials (All Three DP National Laboratories)	Stockpile Stewardship and Reconfiguration	Environmentally Conscious Design Selected and Applications Identified and Demonstrated Third Quarter of 1995 First Selected Product Line Available for Stockpile Use First Quarter of 1997

D. Potential Benefit to DOE Energy Programs:

Enhanced recovery of oil and gas, an initiative of the Office of Energy Research, will benefit from the development of high performance explosives as well as explosives that have enhanced safety.

E. Potential Benefit to the Department of Defense

A large demand exists for high performance, insensitive, low-cost, energetic materials for use in conventional munitions, including strategic and tactical rocket motors, bombs, mines, shaped charges, torpedo warheads, gun propellants, fuel/air explosives, demolition charges, and a wide variety of

other ordnance. These military applications, like nuclear weapons, have very high safety requirements. In addition, environmentally conscious materials developed for DOE applications will be of direct benefit to DoD ordnance and will assist the DoD in meeting new environmental requirements that apply to all future munitions and associated demilitarization and waste disposal processes. Thus, many of the explosive technologies being researched and developed for nuclear weapons have direct application for conventional munitions. Areas of special importance to the DoD include:

- IHE for essentially all munitions;
- insensitive, high performance missile propellants with a reduced signature for detection by the enemy;
- higher energy density explosives for conventional munitions;
- binary propellants for inherent safety;

DEFENSE PROGRAMS RESEARCH and TECHNOLOGY DEVELOPMENT

- improved predictive capabilities for all high energy density materials;
- improved predictive capability for exposure to abnormal environments;
- longer service lifetimes;
- lower lifetime cost, including waste management costs when taken out of service;
- production processes that satisfy ES&H concerns; and
- directed effects using shaped charges.

F. Potential Benefit to National Economic Growth:

The economy will benefit from reductions in the cost to the Nation in making munitions and propellants for the armed forces, as well as destroying them upon their retirement. Thus, some of the

activities in this Program Element will have a direct and lasting benefit for economic growth. Furthermore, benefits will accrue due to international trade in explosive materials for both defense and commercial applications. Consequently, all of the areas discussed above have the potential to benefit our domestic industries. Other areas of interest to the private sector include:

- IHE and high-performance explosives for enhanced recovery of gas and oil and for mining and quarrying;
- insensitive, high performance missile propellants for commercial satellite launching;
- low cost explosives for shock processing of materials;
- highly reliable, low energy initiation systems for automotive airbags, downhole oil well fracture, and mining applications; and
- directed effects using shaped charges.

Glossary

AGEX	AboveGround EXperiments
ASIC	Application Specific Integrated Circuit
CAD	Computer Aided Design
CAM	Computer Aided Manufacturing
CO₂	carbon dioxide
CVD	Chemical Vapor Deposition
D	Deuterium
DDT	Deflagration to Detonation Transition
DNA	Defense Nuclear Agency
DoD	Department of Defense
DOE	Department of Energy
DOE/DP	Office of the DOE's Assistant Secretary for Defense Programs
DOI	Direct Optical Initiation
DP	Office of the DOE's Assistant Secretary for Defense Programs
DRAM	Dynamic Random Access Memory
EMP	ElectroMagnetic Pulse
ENDS	Enhanced Nuclear Detonation Safety
EOS	equation of state
ES&H	Environmental Safety and Health
FALCON	Fission Activated LAsEr CONcept
FRP	Fire Resistant Pit
fsec	femtosecond
g	grams
GaAs	gallium arsenide
GHz	gigahertz (one billion cycles per second)
GPa	gigapascals
GPS	Global Positioning Satellite
GVLS	Global Verification and Location System

HE	High Explosive
He	helium
HgCdTe	mercury-cadmium-tellurium
HMX	High Melt point eXplosive (cyclo tetramethylene tetranitramine)
IC	Integrated Circuit
ICF	Inertial Confinement Fusion
IHE	Insensitive High Explosive
IR	Infrared Radiation
J	Joule
K	Kelvin
keV	thousand electron volts
kV	kilovolts
LANL	Los Alamos National Laboratory
LDI	Laser Diode Ignition
Li	lithium
LIDAR	Light Detection And Ranging
LLNL	Lawrence Livermore National Laboratory
MeV	million electron volts
NCC	Nuclear Command and Control
NDT	NonDestructive Testing
NOVA	a glass laser located at LLNL
nsec	nanosecond
NW	Nuclear Weapon
ORAT	Office of Research and Advanced Technology within DOE/DP
PAL	Permissive Action Link
PE	Program Element
PEP	Program Element Plan
PEX	Paste EXplosive
PRA	Probabilistic Risk Assessment
psec	picosecond
PV	Protected Volume
Pu	plutonium

R&D	Research and Development
R&TD	Research and Technology Development
ROM	Read Only Memory
SAR	Synthetic Aperture Radar
Saturn	a pulsed power intense x-ray source located at SNL
SEU	Single Event Upset
SNL	Sandia National Laboratories
SNM	Special Nuclear Materials
SONOS	Silicon-Oxide Nitride-Oxide Semiconductor
S&P	Synthesis and Processing
SRD	Secret Restricted Data
T	Tritium
TM	Thermal Management
UGT	UnderGround nuclear Testing
W	Watts
WR	War Reserve
Z	particle charge in units of electron charge
μm	micrometer

END

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5/9/94