# CHAPTER XI
# NUCLEAR TECHNOLOGY

## A. INTRODUCTION

Nuclear Technology develops the technical military capabilities that DoD forces and systems need in order to withstand threats and prevail in a range of scenarios in which there might be threats to the United States and its interests:[1]

- Emergence of a confrontation with a nuclear peer adversary.
- A regional contingency or major theater war involving weapons of mass destruction (WMD)-capable adversaries. In such a scenario, adversaries might employ the threat or use of WMD as an asymmetric counter to offset the United States' conventional superiority.
- Terrorist or unconventional WMD threats.[2]

While particular emphasis is given to potential nuclear and radiological threats, many of the products developed have broader applicability.

### 1. Definition and Scope

Nuclear Technology S&T efforts develop, apply, and maintain the technical capabilities needed for accomplishment of the DoD's nuclear missions. It also encompasses applications of nuclear technology in nonnuclear projects that contribute to long-term sustainment of critical nuclear competencies. For example, plasma physics and advanced computational expertise support development and demonstration of new electrothermal-chemical propellants, expertise initially developed for fallout forecasting is applied to estimate the collateral hazards that might be result from a conventional attack on a WMD target, and enabling technologies for radiation-hardened microelectronics and photonics are used to provide protection against both weapon-induced and natural space radiation environmental hazards.

Defense S&T Reliance is a mechanism for coordinating and integrating DoD-wide S&T programs, reducing redundant capabilities, and eliminating unwarranted duplication (Ref. 1).

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[1] Although there are some significant differences between these scenarios with respect to mission requirements and associated technology development needs, they are not mutually exclusive (e.g., during a major theater war, an adversary might employ unconventional threats). To the extent possible, technical activities and capabilities are leveraged to respond to the requirements of multiple missions/scenarios.

[2] In the previous edition of the *Defense Technology Area Plan*, these technical activities were presented in the Chemical/Biological Defense and Nuclear chapter.

Although Nuclear Technology investments are addressed in the Defense S&T Reliance processes, there is additional integration of activities not found in other technology areas. Since the establishment of the Armed Forces Special Weapons Project—the first defense agency—more than a half-century ago, joint technical programs have been emphasized within DoD Nuclear Technology activities. The recent and current situation is that all DoD Nuclear Technology S&T programs are accomplished by a single DoD component, the Defense Threat Reduction Agency (DTRA), which commenced operations on 1 October 1998. DTRA establishment was one of the primary actions directed by the November 1997 Defense Reform Initiative (Ref. 2).

Nuclear Technology investment priorities are based on requirements developed by warfighters; by military department and defense agency acquisition organizations for development and validation of new capabilities (e.g., radiation-resistant technology for new generations of satellites); and by military departments for validation of hardening to support sustainment of strategic and nonstrategic systems. Department-wide plans and activities for sustainment of nuclear mission capabilities are presented in the Secretary of Defense's May 1997 report to Congress on DoD *Nuclear Weapon Systems Sustainment Programs* (Ref. 3).

Figure XI–1 shows the four subareas within Nuclear Technology. The warfighter support subarea involves research and development dealing with weapon–target interactions, to include lethality, energy coupling, damage prediction, collateral effects, and consequence and combat assessment. Additionally, it includes support for end-to-end strategic mission capabilities and strategic systems sustainment.

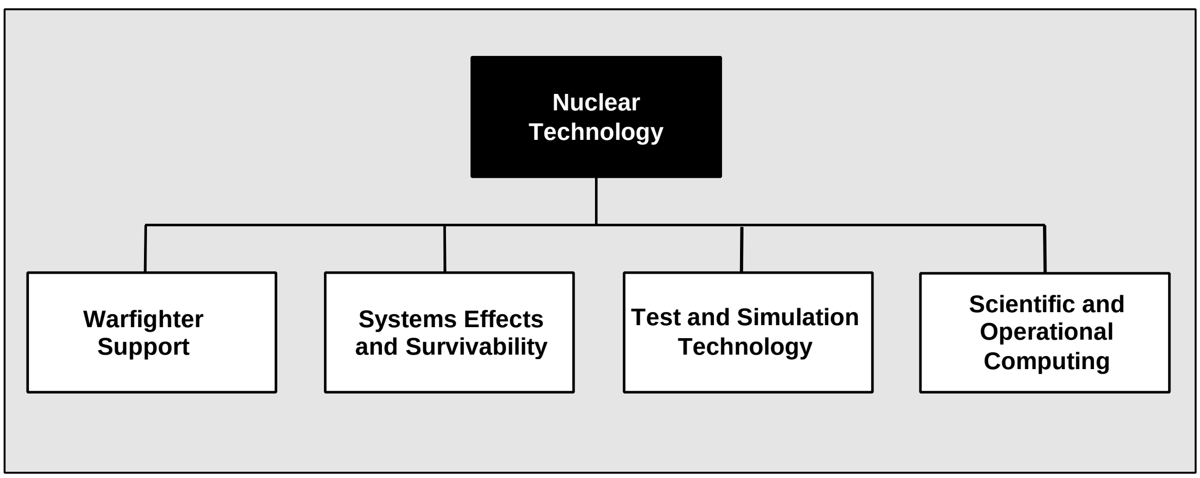


**Figure XI–1. Planning Structure: Nuclear Technology**

The systems effects and survivability subarea develops hardening design and testing protocols and technologies that provide the warfighters with confidence in the survivability of their weapon systems in all nuclear effects environments. The warfighter needs radiation- and electromagnetic (EM)-hardened systems and microelectronic pieceparts in order to survive the threat and perform missions. This subarea has two technical thrusts: the development of affordable state-of-the-art, radiation-hardened microelectronics and photonics; and the integrated hardening, testing, and analysis of military systems against nuclear, EM pulse (EMP), and high-power microwave (HPM) weapons. Additionally, the availability of nuclear weapons technology and sophisticated delivery systems has led to the emergence of a new threat from proliferants: the high-altitude detonation of one or two low-yield weapons. Due to proliferation, this threat of employment in a regional conflict is more likely. This threat places unprotected space and ground systems at risk.

The test and simulation technology subarea develops the simulator and field test capabilities as well as the basic nuclear phenomenology needed to validate the ability of systems to withstand x-ray, blast, thermal, EMP, and other nuclear-weapon-induced threats. These technologies are also used to validate weapons effectiveness and lethality. A small portion of this program, conducted in conjunction with other activities (to minimize costs), responds to presidential guidance by maintaining the capability to resume underground nuclear testing, if this were to be directed.

The scientific and operational computing subarea develops the advanced computational capabilities used in the other subareas. This includes collaboration with DOE for development of virtual testing capabilities in conjunction with the DOE Accelerated Scientific Computing Initiative (ASCI). This subarea also includes efforts to safeguard and apply the technical database developed in past DoD nuclear test activities.

Both test and simulation technology and scientific and operational computing subareas provide enabling technologies for development and application activities within the warfighter support and systems effects and survivability subareas. An interrelationship between the warfighter support and systems effects and survivability subareas is the understanding that weapon–target interactions are an enabling condition for developing technologies to withstand weapon effects, and vice versa.

## 2. Strategic Goals

The primary objective within Nuclear Technology is to develop and validate the technical military capabilities needed by DoD forces and systems to accomplish missions in the three scenarios presented previously. More specific strategic goals, their correspondences with the three primary planning scenarios subareas, and selected technical activities are listed in Table XI–1.

Nuclear Technology develops the technical capabilities needed to support deterrence in new circumstances. These capabilities involve activities that sustain and develop weapons, provide protection against weapon effects, disincentivize acquisition or use of WMD, provide capabilities for denial or defeat of WMD, and defend against proliferant use of such weapons.

## 3. Acquisition/Warfighting Needs

Nuclear Technology provides technical underpinnings for three of the Joint Vision 2010 operational concepts (Ref. 4). Technologies that provide protection against proliferant weapon threats are required to ensure that forces and systems have full-dimensional protection; the same technologies are needed to ensure the survivability of projection forces to accomplish dominant maneuver. Precision engagement requires development of more discriminate weapons that have the lethality needed to hold difficult-to-kill targets at risk with minimized collateral effects.

**Table XI–1. Nuclear Technology Strategic Goals and Their Correspondences With Planning Scenarios and Subareas**

| Nuclear Technology Goals[a] | Primary Scenario | Relevant Subareas | Key Technical Activities Within Subareas |
|---|---|---|---|
| Deter potential peer adversaries and reassure allies | Emergence of a confrontation with a nuclear peer adversary | Systems effects and survivability<br>Test and simulation technology<br>Scientific and operational computing<br>Warfighter support | Strategic systems sustainment technical programs including hardness design and testing protocols, hardness validation via simulators, use of hardened electronics and photonics, virtual testing, and collaboration with DOE for nuclear weapon system sustainment |
| Disincentivize WMD use during regional contingencies | A regional contingency or major theater war involving WMD-capable adversaries. In such a scenario, adversaries might employ the threat or use of WMD as an asymmetric counter to offset the U.S. conventional superiority | Systems effects and survivability<br>Test and simulation technology<br>Scientific and operational computing | Protection against wide-area persistent effects<br>Protection of mission-critical systems and supporting infrastructure |
| Deny sanctuary to WMD weapons and associated $C^3$ | A regional contingency or major theater war involving WMD-capable adversaries. In such a scenario, adversaries might employ the threat or use of WMD as an asymmetric counter to offset the U.S. conventional superiority | Warfighter support | Hold hard-to-kill targets at risk<br>Discriminate lethality weapons<br>Minimize target-induced collateral damage |
| Become impervious to WMD threats/attacks | Terrorist or unconventional WMD threats | Warfighter support<br>Systems effects and survivability<br>Test and simulation technology<br>Scientific and operational computing | Agent defeat/neutralization weapons<br>Collective protection<br>Protection for critical assets and infrastructure<br>Technical support to DoD deployment teams, first responders, law enforcement, etc. |

[a]Some of these categories are not mutually exclusive. For example, during a regional conflict scenario, an adversary might pose unconventional WMD threats. Only key relationships are depicted.

In a strategic environment in which nuclear proliferation continues, the activities presented in this chapter develop enabling technologies needed for accomplishment of Joint Warfighting Capability Objectives (JWCOs). Systems effects and survivability, test and simulation technology, and scientific and operational computing develop and validate the protection technologies that provide the survivability needed for achieving the Sustainment of Strategic Systems, Information Superiority, Force Projection/Dominant Maneuver, and Joint Theater Missile Defense JWCOs. The weapon–target interaction research accomplished in the warfighter support subarea provides the basis for development of new counterproliferation counterforce capabilities in the Counter Weapons of Mass Destruction JWCO, and also provides the basis for developing and validating the new weapon concepts needed in the Precision Force and Electronic Warfare JWCOs. The testing and simulation technology subarea provides the foundation for the structures protection development efforts in the Combating Terrorism JWCO.

Examples of transition opportunities are provided in Table XI–2.

**Table XI–2. Nuclear Technology Transition Opportunities**

| Current Baseline | 5 Years | 10 Years | 15 Years |
|---|---|---|---|
| WARFIGHTER SUPPORT SUBAREA | | | |
| Unable to hold some difficult-to-defeat targets at risk (e.g., deeply buried facilities) | Develop and demonstrate improved capabilities for functional disruption and physical defeat of missiles and WMDs located in tunnels | Extend tunnel target defeat capabilities to include defeat/disruption of $C^2$ tunnel facilities | Developmental priorities to be driven by warfighter requirements which, in turn, will depend on the measures taken by potential adversaries to provide sanctuary for military capabilities |
| Shortfalls in capabilities for prediction and minimization of target-induced collateral effects (e.g., when targets are located in urban areas) | Develop automated system for predicting target-induced collateral hazard transport associated with attacks on WMD targets | Develop capability for predicting effects transport in urban environments | Exploit developments in real-time higher resolution meteorological forecasting to provide higher resolution forecasts for collateral hazards |
| Warfighters do not have a standardized weaponeering capability that encompasses the full spectrum of weapons and targets | Demonstrate integrated weaponeering capability for current weapons and targets of interest | Adapt weaponeering capability to incorporate new planning and combat assessment systems under development within military departments | Adapt weaponeering capability to incorporate new planning and combat assessment systems under development within military departments |
| Effort initiated, in collaboration with DOE, on unprecedented program to sustain nuclear capabilities without nuclear testing | Complete dual revalidation of weapons in enduring stockpile; complete development and application of safety methodology for START II force structure | Technical activities will respond to requirements identified in the course of stockpile/nuclear force structure surveillance and needs identified by the military departments and JCS | Develop technologies needed to support sustainment of modernized or follow-on strategic forces |
| SYSTEMS EFFECTS AND SURVIVABILITY SUBAREA | | | |
| Successive generations of microelectronics used in space systems and other critical military systems are inherently more susceptible to radiation-induced damage | Develop and demonstrate 0.25-μm radiation-hardening technology for system-on-a-chip devices and hardened photonics | Develop and demonstrate electronic automation technology for next generation(s) of microelectronics and photonics | Developmental priorities driven by progress in fast-paced microelectronics industry in which a generation can be 18 months. Enabling technology for radiation hardening needed to support use of COTS technology in DoD space systems |

**Table XI–2. Nuclear Technology Transition Opportunities (cont'd)**

| Current Baseline | 5 Years | 10 Years | 15 Years |
|---|---|---|---|
| SYSTEMS EFFECTS AND SURVIVABILITY SUBAREA (cont'd) | | | |
| Current system hardening methodologies are inefficient; they provide protection for specific hazards rather than more cost-effective protection against multiple threats | Transfer to military departments proven hardware and software technologies and test techniques for integrated protection against both EMP and HPM threats | Develop and transfer to military department acquisition organizations the technologies and tools needed for protection against new RF weapon threats | Developmental priorities to be based on requirements of DoD system development organizations |
| TEST AND SIMULATION TECHNOLOGY SUBAREA | | | |
| With the end of underground nuclear effects testing, there are shortfalls in simulation capabilities (fluence, spectrum, and test area) | DECADE Radiation Test Facility to come on line, providing twofold improvement in hot x-ray capability and threefold improvement for cold x-rays | Simulator support for validating hardening of NMD systems (e.g., Advanced Nuclear Seeker Clutter Simulator) | Activities to be driven by requirements associated with systems that have hardening validation requirements (e.g., missile defenses) |
| Shortfalls in understanding and application of nuclear phenomenology physics result in targeting that does not make optimal use of all weapon effects | Target planning takes into consideration a wider range of combined effects | Optimized targeting based on better understanding of both specific and combined effects | Improved use of both specific and combined effects in targeting based on refined understanding of phenomenology, target characteristics, and weapon/target interactions |
| There are shortfalls in testbed capabilities for simulating terrorist bomb threats and for the evaluation of protective measures to counter these hazards | Complete upgrades to LB/TS to provide better capabilities for antiterrorism testing | Technical efforts responsive to requirements defined by warfighters, responders, and system developers | Technical efforts responsive to requirements defined by warfighters, responders, and system developers |
| SCIENTIFIC AND OPERATIONAL COMPUTING SUBAREA | | | |
| DOE is sponsoring development of a new class of computational capabilities (hardware and software) to provide the technical foundations for Science-Based Stockpile Stewardship | Develop advanced computational capabilities required for DoD–DOE partnership in ASCI and other activities supporting nuclear weapon systems sustainment<br>Begin use of virtual testing based on advanced modeling and simulation capabilities | Continue to develop computational capabilities needed for then-current state-of-the-art support for nuclear weapon systems sustainment by DoD and by DoD in partnership with DOE<br>Continue to develop, validate, and apply virtual testing capabilities | Continue to develop computational capabilities needed for then-current state-of-the-art support for nuclear weapon systems sustainment by DoD and by DoD in partnership with DOE<br>Continue to develop, validate, and apply virtual testing capabilities |
| Unique database from DoD nuclear test and simulator programs needs to be reviewed and archived | Complete review and archiving of primary nuclear testing and simulator databases | Complete review and preservation of system response/susceptibility data for TREE, SGEMP, and HEMP effects | Complete review and archiving of initial phase data from DoD and DoD–DOE nuclear sustainment programs |

## B. DEFENSE TECHNOLOGY OBJECTIVES

Defense Technology Objectives[3] by subarea are:

*Warfighter Support*

NT.03 Hard-Target Defeat
NT.04 Prediction and Mitigation of Collateral Hazards
NT.07 Integrated Comprehensive Weaponeering Capability
NT.08 Nuclear Weapon Safety and Reliability

*Systems Effects and Survivability*

NT.02 Electronic System Radiation Hardening
NT.05 Balanced Electromagnetic Hardening Technology
NT.06 Survivability Assessments Technology

*Test and Simulation Technology*

NT.01 Nuclear Operability and Survivability Testing Technologies
NT.09 Nuclear Phenomenology

*Scientific and Operational Computing*

None.

## C. TECHNOLOGY DESCRIPTIONS

### 1. Warfighter Support

#### a. *Warfighter Needs*

Warfighter support involves research and development dealing with weapon–target interactions, to include lethality, energy coupling, damage prediction, collateral effects, consequence, and combat assessment, plus support for end-to-end strategic mission capabilities and strategic systems sustainment. These activities are directed at three of the Nuclear Technology strategic goals.

In order to deter potential peer adversaries and reassure allies, sustainment of end-to-end strategic system capabilities is needed. Over the near term, this involves efforts to appraise and enhance the safety, security, and effectiveness of these forces, to include activities in collaboration with DOE (DTO NT.08, Nuclear Weapon Safety and Reliability). One priority is to provide national leaders with improved options by increasing the responsiveness of strategic forces and developing more discriminate options, as done most recently with the introduction of the B61–11 earth-penetrating-weapons. Transition targets involve the nuclear force structure established in the QDR (Ref. 5).

To accomplish the goal of denying sanctuary to WMD and associated $C^3$, there are a number of near-term and longer term objectives. The first is to develop weapons that can hold hard-to-defeat targets at risk, the focus of DTO NT.03, Hard Target Defeat. The related second and

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[3] In the 1998 DTO document, these DTOs were included in the Chemical/Biological Defense and Nuclear area (DTO prefix “CB”).

third objectives involve development of more discriminate weapons and the minimization of target-induced collateral damage (DTO NT.04, Prediction and Minimization of Collateral Hazards). DTO NT.07, Integrated Comprehensive Weaponeering Capability (ICWC), supports the other objectives by providing planners with improved capabilities for selecting the most appropriate munitions options for specific targets. Initial transitions will be through demonstrations (e.g., ACTDs, TDs) outside of the Nuclear Technology area.

To achieve the objective of being impervious to WMD threats, it is necessary to develop the capability to neutralize agent threats. This is accomplished through technical base efforts that develop the capabilities being demonstrated in the Counter Weapons of Mass Destruction JWCO, notably DTO J.04, Counterproliferation II ACTD.

**b.** ***Overview***

**(1) Goals and Timeframes.** Goals of the warfighter support subarea are presented in Table XI–3.

**(2) Major Technical Challenges.** Although nuclear weapons system sustainment is not a new mission for DoD (Ref. 3), both circumstances (absence of nuclear testing) and methodology (notably, reliance on advanced computational techniques) are unprecedented. Surveillance will be intensive, but some of the technical problems that will need to be addressed may occur with little advance warning. End-to-end planning capabilities need to be adapted to respond to new requirements to provide more responsive forces and to better enable planners to appraise weaponeering options. Full-physics effects models must be translated into operational planning and visualization tools. Past research and development for collateral effects prediction has not focused at the level of resolution that is now needed; has not provided high-fidelity estimates for urban areas, where small-scale microclimate effects are important; and has not focused on target-induced collateral hazards for targets whose source terms may have to be estimated. Agent defeat weapons are new type of munitions for which new technical issues must be addressed.

**(3) Related Federal and Private Sector Efforts.** DOE stockpile revalidation and other Science-Based Stockpile Stewardship (SBSS) activities are critical for accomplishing DoD nuclear missions. Decisions concerning the downsizing and reconfiguration of radiation effects simulators gave explicit consideration to DOE facilities. To the extent possible, use is made of DOE facilities. To promote collaboration, DTRA has assigned personnel to the DOE nuclear weapon laboratories. There is coordination between DTRA and Air Force agent defeat programs, including ongoing work with AF/XON; this department-wide agent defeat research and development was reviewed at a DDR&E-directed workshop held in September 1997.

**c.** ***S&T Investment Strategy***

**(1) Technology Demonstrations.** Demonstrations are typically conducted outside of the Nuclear Technology area (e.g., in the activities within the Counter Weapons of Mass Destruction JWCO).

**Table XI–3. Warfighter Support Goals**

| FY | Goal |
|---|---|
| 1999 | Complete tunnel testbed facility (simulated missile operations facility) at Nevada Test Site; develop signature database.<br>Integrate the natural hazard capability with the capability for predicting WMD hazard health impacts. Calculate mean doses and probabilities of detection or kill while estimating weather uncertainty.<br>Complete dual-revalidation of W–76.<br>Demonstrate ICWC I during a mini-exercise; increase weaponeering throughput and reduce training requirements by 2X; increase functional integration by demonstrating connectivity of four tools.<br>Complete DCA (Europe) weapon system assessment. |
| 2000 | Demonstrate a significant improvement in the ability for long-range, high-resolution forecasting of WMD health hazards (rain-out and scavenging). Validate capability to estimate transport errors and probabilities due to weather prediction, source, transport, and other uncertainties.<br>Demonstrate a capability to deny and disrupt operational (missile) tunnel facilities for a minimum of 48 hours using current conventional weapons; develop and incorporate target reconstitution models. Begin construction on tunnel testbed #2 (WMD production/storage).<br>Deliver the warfighter ICWC I with initial set of weaponeering capabilities that have a common look and feel; begin ICWC II with additional tools and enhanced functional integration. |
| 2001 | Complete MEA Tunnel Module Version 2.0 (Missile Ops Tunnels). Prepare attack plans for tunnel testbed #2. Demonstrate the effectiveness of nuclear weapon capabilities in defeating deep structures using precise, low-yield attacks by HE simulation.<br>Demonstrate ICWC II during a mini-exercise that supports Counterproliferation II ACTD; integrate three additional tools, increase weaponeering throughput by 2X, and reduce training requirements by 5X.<br>Demonstrate an integrated, automated capability for predicting collateral hazards to human populations resulting from possible dispersal of chemical or biological agents and radiation released during or after attacks on WMD targets. Complete urban transport/effects capability at city scale resolution. Test and exercise initial street and building scale resolution capability. |
| 2002 | Demonstrate a capability to deny and disrupt WMD production and storage facilities located in tunnels for at least 7 days with current and advanced conventional weapons. Encompass data into MEA Tunnel Module Version 3.0<br>Provide final Counterproliferation II ACTD capabilities<br>Deliver ICWC II; begin ICWC III with the final set of tools and full functional integration. |
| 2003 | Construct testbed #3, a simulated $C^2$ facility.<br>Demonstrate ICWC III during an operational exercise; increase weaponeering throughput by 10X; reduce training requirements by 20X; deliver ICWC III.<br>Validate prediction methodology using scaled tests of nuclear weapon storage facilities and hardened targets such as tunnels. Complete validation of urban transport/effects capabilities including street and building scale resolution. |
| 2004 | Deliver full-capability urban transport/effects capability for counterproliferation and domestic applications. |
| 2005 | Conduct simulated nuclear assessment in tunnel testbed #3.<br>Provide hazard prediction capability for additional toxic materials, weapons, and target classes to support counterproliferation applications. |

**(2) Technology Development.** Primary technical activities within this subarea correspond to its DTOs:

*NT.08, Nuclear Weapon Safety and Reliability*. Probabilistic risk assessment methodologies have been enhanced and adapted to provide the basis for nuclear force safety assessments. Software engineering technologies are utilized to develop more responsive mission planning and execution capabilities.

*NT.03, Hard Target Defeat*. This work develops physics-based weapon–target interaction models and simulations to estimate consequences of attacks; the existing and emerging state of the art in sensors is used to characterize targets and accomplish combat assessment.

*NT.04, Prediction and Mitigation of Collateral Hazards.* This program involves meteorology, research on atmospheric transport, weapon–target interaction modeling, and estimation of source terms for target-induced hazards.

*NT.07, Integrated Comprehensive Weaponeering Capability*. This program employs software engineering to integrate weaponeering, collateral hazard assessment, and combat assessment tools. Applied physics (e.g., for weapon–target interactions/target response) provides the foundation for this integration.

**(3) Basic Research.** There are no DoD warfighter support basic research programs.

## 2. Systems Effects and Survivability

### a. *Warfighter Needs*

The systems effects and survivability subarea develops hardening design and testing protocols and technologies that provide the warfighters with confidence in the survivability of their weapon systems in all nuclear effects environments. This subarea has two technical thrusts: the development of affordable state-of-the-art, radiation-hardened microelectronics and photonics; and the integrated hardening and testing and analysis of military systems against nuclear, EMP, and HPM weapons.

Strategic system sustainment is needed to accomplish the goal of deterring potential peer adversaries and reassuring allies. Over time, some components of these systems will have to be replaced or modified. This subarea develops the hardness design and testing protocols needed to sustain mission capability and support hardness validation testing. The material response program will characterize the x-ray response of optical materials. The system survivability data program will gather underground test (UGT) data, improve analysis tools, and apply these tools to support strategic modernization and life-extension programs.

For the foreseeable future, the United States is likely to have conventional superiority in any regional confrontation or conflict. Adversaries may be tempted to employ the threat or use of WMD as an asymmetric counter to offset this conventional superiority, such as use of a few weapons to destroy or damage satellites, $C^4I$ systems, and other capabilities needed for full-spectrum dominance. Hence, this subarea develops radiation and EM effects-hardened systems and microelectronic pieceparts that can survive such threats. DoD has unique needs for radiation-hardened microelectronics that can survive radiation fluence levels that commercial-off-the-shelf

(COTS) microelectronics cannot satisfy. DTRA activities for maintaining the capabilities for radiation-hard microelectronics are presented in the Secretary of Defense's June 1996 report to Congress on the Long-Term Radiation Tolerant Microelectronics Program (Ref. 7).

Technologies developed in this subarea also contribute to the objective of withstanding terrorist and unconventional threats. DoD is increasingly using the civilian infrastructure to support operations. Unless protected, this critical infrastructure is at risk to RF weapons and related threats.

### b. *Overview*

**(1) Goals and Timeframes.** Goals of the systems effects and survivability subarea are presented in Table XI–4.

**Table XI-4. Systems Effects and Survivability Goals**

| FY | Goal |
|---|---|
| 1999 | Demonstrate radiation-hardened submicron (0.35-µm) technology for 16X reduction in weight and power.<br>Demonstrate an optical material systems-level analysis predictor and capture strategic system UGT materials data; deliver a validated sensor protocol; deliver a draft reentry system protocol.<br>Demonstrate hardened ac power cord. Test COTS equipment. Demonstrate generic hardening techniques for information operations hardware during an OSD-sponsored exercise.<br>Complete initial GPS operability assessment. |
| 2000 | Demonstrate deep-submicron (0.25-µm) technology for radiation-hardened, low-power microelectronics technology for l00X reduction in weight and power; develop hardening techniques for advanced sensors.<br>Apply materials UGT data to develop an impulse characterization model. Demonstrate integrated EMP/HPM test methods. Integrate witness chip RF attack detector in existing COTS and MILSPEC equipment.<br>Demonstrate automated process for performing operability assessments. Complete GPS full constellation assessment tool. |
| 2001 | Demonstrate technology for 16-Mb SRAM, 4,000k gate array and 32-bit, >100-mips digital signal processor.<br>Transfer proven EMP/HPM hardware and software technologies, including a generic simple-to-install hardware kit for hardening COTS computers, and test techniques to the services.<br>Conduct advanced data communications assessment; demonstrate network analysis tool. |
| 2002 | Develop final protocols for reentry systems, and demonstrate hardened advanced sensors. Develop a strategic system material stress propagation model.<br>Assess EM protection to emerging RF threats. Investigate use of proven hardening techniques in offensive weapon delivery systems.<br>Assess operability/connectivity of the NORAD/USSPACECOM advanced $C^2$ systems for operation in nuclear weapons effects. |
| 2003 | Update MIL–STD–188–125 and MIL–STD–2169.<br>Assess the evolving TMD $C^3$ architectures for operation in nuclear weapons effects; assess the operability of future DII architectures to support strategic warfighter needs. |
| 2004 | Develop 0.18-µm radiation-hardened, mixed-signal technology including silicon-germanium bipolar transistors for silicon-on-a-chip applications. |
| 2005 | Develop electronic automation technology to demonstrate radiation-hardened 0.18-µm CMOS system-on-a-chip for next-generation military space systems. |

**(2) Major Technical Challenges.** Military systems continually require increased information processing, but state-of-the-art commercial semiconductor processes are designed primarily to maximize profits, usually at the expense of such characteristics as radiation hardness. Thus, succeeding generations of microelectronics have become increasingly susceptible to radiation. DoD must maintain an ongoing effort to radiation harden new generations of microelectronics as they evolve to ensure that warfighters have the survivable state-of-the-art electronics systems needed to survive high-altitude EMP (HEMP), HPM, microwave, and ballistic missile defense-related x-ray threats. Additionally, the ban on underground testing requires the development of new designs, test protocols, and procedures that ensure system survivability, and these must be integrated into DoD planning for strategic systems sustainment and the DOE Stockpile Stewardship Management Plan (SSMP). Another set of challenges involves measures to provide military and civilian facilities with improved protection against terrorist threats.

**(3) Related Federal and Private Sector Efforts.** Radiation-hardened electronics are critical for the multibillion dollar commercial and civilian space industries. Commercial space system firms have no interest in producing radiation-hardened microelectronics. However, radiation-hardened efforts are conducted by DOE and NASA. The DTRA microelectronics-enabling technology efforts are coordinated with the programs of DoD system program officers, as well as the Sandia (DOE) National Laboratory and the Goddard and Jet Propulsion Laboratory (NASA) radiation-hardened microelectronics programs.

Balanced hardening methodologies have considerable potential for transfer to the private sector. Notable is the proposed use of European Union protection standards that are more stringent than their U.S. commercial equivalents. DTRA enabling technology efforts are coordinated with the programs of DoD system program offices that make use of these technologies in system development activities. The presidential Critical Infrastructure Protection Initiative provides an opportunity to improve civil sector practices and standards to make critical infrastructure inherently more robust.

### c. *S&T Investment Strategy*

**(1) Technology Demonstrations.** This subarea emphasizes development of enabling technology, with demonstrations being conducted in other technology areas (e.g., DTO SE.37, High-Density, Radiation-Resistant Microelectronics).

**(2) Technology Development.** Technical activities within this subarea align with its DTOs.

*NT.02, Electronic System Radiation Hardening*. The major objective—a DDR&E-directed priority—is development of radiation-hardened electronics enabling technology for missiles and space systems that could be exposed to proliferant nuclear weapons effects. A second objective is to ensure that the communications and sensors of these space assets are not disrupted by the disturbed environment caused by such a high-altitude event. The final objective is to ensure the ground terminals associated with these assets are protected from the HEMP that such an event can produce. Toward these ends, the threats posed by a proliferant's weapons are being better characterized, and methods for protecting and testing that protection are being developed. This type of electronics technology is required to validate the survivability of space and missile systems such as MILSATCOM, SBIRS, GBI, GPS, USSTRATCOM weapons, Space-Based

Radar, Space-Based Laser, and $C^4I$ systems. This enabling technology forms the basis from which DTO SE.37, High-Density, Radiation-Resistant Microelectronics, produces final products for space and missile systems.

*NT.05, Balanced Electromagnetic Hardening Technology*. The objective in this program is to develop and demonstrate integrated hardening technology and methodologies. These methodologies would reduce costs by allowing a smaller number of validated tests to be conducted to verify protection against multiple hazards. Technology development would involve new lower cost approaches for integrated effects testing and protection validation. This approach is congruent with new DoD acquisition policies mandating much greater use of commercial parts and standards. Priority would be given to protection against HPM and HEMP effects with consideration given to the whole spectrum of EM interferences and disturbances. The goal is to achieve the optimum EM protection for systems balancing the competing factors of threat, cost, size/weight, and technical/engineering feasibility.

*NT.06, Survivability Assessments Technology*. The objective of this program is to perform operability, survivability, vulnerability, and connectivity assessments for current and proposed systems in combined nuclear effects environments. The identification and capture of relevant system data is the starting point for these assessments. This baseline program applies DTRA expertise in support of warfighting CINCs and service needs for affordable and responsive solutions to meet survivability requirements. These same tools are applied to evaluate and analyze potential mitigation solutions for systems that must operate during and through a nuclear engagement. This program responds to requirements identified by JCS, combatant CINCs, services, and other DoD organizations. The goals of the program are to conduct timely, accurate, and relevant assessments of components, systems, networks, and systems of systems.

**(3) Basic Research.** There are no DoD systems effects and survivability basic research programs.

## 3. Test and Simulation Technology

### a. *Warfighter Needs*

The test and simulation technology subarea develops the simulator and field test capabilities needed to validate the ability of systems to withstand nuclear produced x-ray, blast, thermal, EMP, atmospheric propagation and infrared radiance, and other effects. These technologies are also used to validate weapons effectiveness and lethality. A small portion of this program, conducted in conjunction with other activities to minimize costs, responds to presidential guidance by maintaining the capability to resume underground nuclear testing, if this were to be directed. An important aspect of this subarea is the development and improvement of the nuclear phenomenology models that define the environments to be simulated.

These technology development efforts respond to Presidential Decision Directive 15 and other national and department direction by providing the capabilities needed to validate military system performance in nuclear and related weapon environments. In the absence of underground tests and without the ability to simulate nuclear weapons effects, there can be little confidence in the ability of military systems to operate in such environments. Sustainment of DoD strategic capabilities requires test and simulation technology to ensure end-to-end confidence in critical delivery and $C^3I$ systems.

**b. *Overview***

**(1) Goals and Timeframes.** Goals of the test and simulation technology subarea are presented in Table XI–5.

**Table XI–5. Test and Simulation Technology Goals**

| FY | Goal |
|---|---|
| 1999 | DECADE Radiation Test Facility (DRTF) IOC provides twofold improvement in hot x-ray capability.<br>Provide hard target lethality technology tool to USSTRATCOM.<br>Complete development of the advanced early-time trapped radiation analysis tool; begin initial development of EMP vulnerability analysis tool; begin initial development of SREMP prediction tool. |
| 2000 | Complete foreign nuclear weapons effects output documentation for point designs.<br>Threefold improvement in cold x-ray test capability available at the DRTF.<br>Begin the integration of high-altitude phenomenology into the space weather model. |
| 2001 | Economization upgrades of LB/TS improve utility for counterterrorism testing.<br>Provide new-generation fallout calculation techniques.<br>Demonstrate EMP vulnerability analysis tool and SREMP prediction tool. |
| 2002 | Complete documentation of output energy coupling transport based on weapon output from SSMP-driven warhead modifications and calculations.<br>Improve scene generation dynamic display technology for nuclear infrared clutter simulator. |
| 2003 | High-fidelity (high dose, high dose rate) hot x-ray test upgrades implemented on DECADE.<br>Complete updating and revision of EMP/SREMP analytical techniques used by warfighters.<br>Wideband Channel Simulator operational to support advanced MILSATCOM. |
| 2004 | Advanced Nuclear Seeker Clutter Simulator supports NMD seeker testing.<br>Conduct laser/fireball test in National Ignition Facility (NIF) to improve understanding in-tunnel airblast.<br>Increased bandwidth of Advanced Channel Simulator supports MILSATCOM testing.<br>Demonstrate integration of high-altitude phenomenology into the space weather model. |
| 2005 | Full operation of NIF supports nuclear effects x-ray testing.<br>Complete total revision of high-altitude nuclear weapons codes and their transfer to massively parallel computers. |

**(2) Major Technical Challenges.** Given termination of underground nuclear tests, there are significant shortfalls in the ability of radiation simulators to reproduce the environments from nuclear weapons detonations with adequate intensity, exposure area, and temporal and spectral fidelity. Due to funding constraints, investment in new, potentially more cost-effective simulation technologies has been curtailed. This effort focuses on consolidating existing facilities, completing ongoing development efforts, and incrementally improving in-place capabilities.

For radiation simulation, there are major shortfalls in capabilities for testing full-size systems or subsystems against all types of x-rays. With the underground testing moratorium, the ability to test the response of materials, optics, and structures to the cold and warm portion (under 40 keV) of the x-ray threat has been severely curtailed. Plasma radiation sources implemented on existing simulators are attempting to fill this gap. At present, available debris-free fluence areas are approximately 5 cal/$cm^2$ over several $cm^2$. Investigation of innovative and efficient cold x-ray sources with ten times larger debris-free fluences and better fidelity continues. By the year 2000, the goal is to improve debris-free cold x-ray test capability by a factor of 300 based on improvements in plasma radiation sources and debris shields.

DECADE will provide the capability to test the response of small systems to hot x-rays (>40 keV). DECADE will be constructed in phases. The first phase (DECADE Quad) will provide a 20,000-rad dose over 2,500 $cm^2$, providing a 200% increase in performance over current hot x-ray simulators. Subsequent improvements will provide high dose and dose rate for strategic component and system testing as well as improved spectral fidelity through lower end point voltage.

Improvements are needed in cold x-ray plasma radiation source fidelity and stability, debris shields to provide high-fidelity test environments for plasma radiation sources, reliability and repeatability of plasma switches used in radiation simulators, synchronous use of modular pulsed power devices, and diagnostics that can function in the harsh environments produced by x-ray simulators. Also to be examined and developed are technology options for the development of a “full threat radiation simulator” so that this technology will be available when needed.

The Magnetic Flyer facility will provide an interim capability to simulate shock and impulse loading effects of cold and warm x-rays until an adequate x-ray test capability is available. The Magnetic Flyer will be operated to support U.S. and allied strategic system testing.

In blast/thermal simulation, improvements to the Large Blast/Thermal Simulator (LB/TS) are needed in blast ignition and venting and cryogenic gas systems to significantly reduce the operating cost of the LB/TS. Unmet requirements include improved high-temperature, high-flux thermal sources and the ability to simulate a wider range of blast phenomenologies.

High-explosive (HE) test facilities will be operated and improved to support counterproliferation and counterterrorism programs.

Effort continues to improve simulations of atmospheric nuclear effects on communications, radar, and infrared sensor systems. Steps are being taken to improve the bandwidth of the Advanced Channel Simulator to support emerging MILSATCOM requirements. The Radar Nuclear Effects Corruptor and Simulator (RNECS) is currently under development. RNECS will support testing to characterize the performance of ground-based radars, ballistic missile early warning systems, and other radars.

The Nuclear Infrared Clutter Simulator is used to generate target and background scenes in a cryogenic vacuum chamber and project them on system focal planes. This will improve support for customer testing by the development and incorporation of user-friendly electronics that fully utilize the capabilities of the Nuclear Optic Dynamic Display System (NODDS). These will be integrated into an Advanced Nuclear Clutter Simulator (ANCS) to support National Missile Defense (NMD) Ground-Based Interceptor (GBI) seeker testing. As higher resolution (e.g., 1024 x 1024) NODDS chips are developed, they will be incorporated into ANCS.

Desktop assessment tools will be developed to support the warfighter, including a wide range of nuclear effects such as EMP, atmospheric effects, and thermal and mechanical phenomenology. Improved weapons output modeling will provide a foundation for these assessment tools.

Underground testing readiness is being accomplished through the combination of a bare-bones investment in test site infrastructure and development of a reconstitution plan showing what must be done to reconstitute a test capability if this is directed by national authorities at some point in the future.

Nuclear phenomenology research will employ physics research and advanced computational tools to develop and understand nuclear weapon free-field and lethality information and to provide nuclear weapon effects information to warfighters in usable forms. One technical priority is to develop better estimates of the damage that might be induced by the secondary effects of nuclear weapons, (e.g., fire, EMP, fallout). In other phenomenology research, DoD will begin experiments at the DOE NIF, and documentation will be developed for output energy coupling transport based on weapon outputs from SBSS-driven warhead modifications and calculations. Furthermore, analytical tool development is based on a small sample size of empirical test data. Additionally, the tools require myriad numerical calculations to provide a relatively accurate assessment

**(3) Related Federal and Private Sector Efforts.** S&T planning gives consideration to the use of DOE simulators to respond to DoD requirements. DOE plans and development efforts that, if successful, might respond to DoD needs are being monitored (e.g., the NIF at LLNL, X–1 proposed by Sandia National Laboratory, and other SSMP programs). Significant opportunities for technology transfer to the private sector are associated with some of the technologies in this subarea, including high-energy density capacitors (medical, radar, and commercial power system applications), flash x-ray technology (food processing sterilization, exhaust gas cleanup from fossil fuel powerplants), and x-ray modeling and source development for medical therapy (higher resolution, lower exposure, improved diagnostics).

**c. *S&T Investment Strategy***

**(1) Technology Demonstrations.** This subarea develops facilities that support the warfighter support and the systems effects and survivability subareas. No demonstrations are planned.

**(2) Technology Development**. Technical activities within this subarea align with its DTOs.

*NT.09, Nuclear Phenomenology*. The objective is to develop an understanding of nuclear weapons effects phenomenology, develop and understand the nuclear-weapon-related free field, provide nuclear weapon target interaction lethality information, and provide nuclear weapons phenomenology information to the warfighter in usable form. The DTO addresses the lethality of the full spectrum of nuclear weapons and applies directly to the understanding of weapon target interaction to support the generation of weapon system requirements for the changing worldwide target base as well as providing for the understanding of nuclear weapons effects and their consequences for battle damage prediction and assessment.

*NT.01, Nuclear Operability and Survivability Testing Technologies*. The objective is to provide the means to validate/revalidate the survivability and operability of military systems in a proliferant nuclear threat environment. Underground nuclear testing was a major means used to validate system survivability and vulnerability. However, with the cessation of underground nuclear testing, full-scale subsystem/system hardening validation and survivability testing of both new and existing nuclear delivery systems in UGTs have been eliminated. Present above-ground x-ray simulation facilities cannot provide the fluence spectrum or exposure area necessary to test systems larger than 2,500 $cm^2$. Present blast, shock, and thermal test facilities also cannot produce the "true" nuclear effects environment. LB/TS provides a repeatable blast/thermal capability; programmed enhancements will improve its utility for antiterrorism testing. With major inputs from a DoD Reliance task force, the DoD nuclear effects simulator suite is being consolidated, and the DECADE Radiation Test Facility is being developed to provide enhanced cold and hot x-ray capabilities. In line with national direction, a bare-bones capability for resumption of testing is being sustained at the Nevada Test Site.

**(3) Basic Research**. There are no DoD test and simulation technology basic research programs.

## 4. Scientific and Operational Computing

### a. *Warfighter Needs*

Scientific and operational computing develops the advanced computational capabilities used in the other subareas. This includes collaboration with DOE for development of virtual testing capabilities, including collaboration with the DOE ASCI. This subarea also includes efforts to safeguard and apply the technical database developed in past DoD nuclear test activities. Preservation and application continue to be major themes in computing activities that respond to warfighter requirements for survivable systems and effective nuclear weapons. Preservation is important because DoD's understanding of nuclear weapon effects is based in large part on test data that are unique and, in many instances, perishable. Applications involve the packaging of U.S. nuclear data and physics understanding into advanced computational products that enable fundamentally new capabilities for warfighter interaction and visualization. In addition, aspects of our understanding of nuclear matters require utilization of advanced computational resources, such as investigating the physics involved in weapon–target interactions and extrapolating from test results in circumstances in which new tests are not possible.

### b. *Overview*

**(1) Goals and Timeframes.** Goals of the scientific and operational computing subarea are presented in Table XI–6.

**Table XI–6. Scientific and Operational Computing Goals**

| FY | Goal |
|---|---|
| 1999 | Continue legacy document population into the Data Archival and Retrieval Enhancement (DARE) system; continue incorporation of atmospheric and underground nuclear test data into DARE; begin preparation of DARE guide to blast effects on structures.<br>Accelerate Graybeard document review activities on ionization and EM effects; begin Graybeard document review activities on thermomechanical and biological effects; complete Graybeard free-field airblast data commentary.<br>Publish DTRA-sponsored tri-service conventional weapons effects protective structures design manual.<br>Establish intrinsic radiation transition repository. |
| 2000 | Continue legacy document population, and begin entry of nuclear simulation data into the DARE system; expand online access to DARE classified and unclassified resources; integrate automated test data recorder interface into DARE archive; expand DARE video capabilities and data visualization tools.<br>Complete Graybeard work on high-altitude nuclear effects; initiate Graybeard mentoring program. |
| 2001 | Complete Graybeard work on biological effects, airblast, cratering and ejecta, and dust/fallout areas.<br>Complete incorporation of reviewed nuclear testing data; develop initial DARE interface to external data archives, including search/retrieve capability (e.g., DTIC, DOE, etc.). |
| 2002 | Complete Graybeard work on structures, ionization, and EM radiation (TREE, SGEMP, EMP) effects; begin validation of Graybeard shock physics domain.<br>Demonstrate high-performance-computer code interface to DARE; begin integration of DARE analytical tools with Graybeard knowledge base. |
| 2003 | Complete Graybeard work on thermomechanical effects; begin validation of Graybeard radiation domain.<br>Complete implementation of DARE interfaces to major external automated data archival systems (DoD, DOE). |
| 2004 | Complete remaining preservation work on all NWE domains; expand knowledge base of cooperative threat reduction and onsite inspection program data.<br>Complete validation of Graybeard shock physics domain; begin investigation of advisory system using DARE/Graybeard information and knowledge base. |

**(2) Major Technical Challenges.** The nuclear effects computations program develops tools for accurate prediction of the evolution of turbulent fields embedded in explosions. Turbulent mixing remains the central unresolved physics problem for virtually all fluid-dynamic phenomena associated with explosions. Past work emphasized nuclear effects topics, and future work will be applied to virtual testing of nuclear effects (to include the turbulent mixing in bomb implosions that is critical in stockpile revalidation (e.g., DOE ASCI)). Current focuses include developing end-to-end simulation capabilities for modeling explosion effects related to counterproliferation and counterterrorism scenarios, such as explosions in buried chamber systems for military applications and explosions in or near buildings for civilian applications. Simulations include characterization of the sources due to such explosions and subsequent local dispersion; and characterization of large-scale transport of contaminants, including the effects of terrain, atmospheric stratification, and local meteorology. The capability to perform detailed first-principles calculations of such turbulent explosion fields has been enabled by development of high-resolution adaptive numerical methods within this program. Results of such analysis provide vital input to military strategy for counterproliferation measures, have aided forensic investigations of terrorist bombing incidents (Khobar Towers, World Trade Center, Oklahoma City), and suggest methods of protecting U.S. troops and civilians abroad and at home.

In a military scenario of an attack on an underground bunker filled with chemical/biological weapons, consequences must be predicted: (1) What is the evolution in space and time of the energy released during the explosion? (2) Will this energy release destroy the structure? (3) Will the chemical/biological weapons be breached? (4) Will the agent be destroyed by the high-temperature environment of the explosion? (5) How much of the agent will be ejected from the bunker? (6) How will the agent be dispersed in the atmosphere and at what risk to civilian populations? Likewise, the application of explosion science to the analysis of terrorist bombing incidents provides valuable technical inputs (e.g., How much explosive is consistent with the observed damage?) to forensic investigations by DoD and FBI. This program combines the advanced computer architectures available in the DoD High-Performance Computing Modernization Program and the DOE ASCI effort with sophisticated adaptive numerical methodology to simulate the three-dimensional, time-dependent explosion field relevant to these applications.

A complete simulation capability requires modeling fluid-dynamic phenomena in three different regimes: explosions in complex geometries, ejection of explosion plumes, and atmospheric transport of contaminant clouds. The overall goal in this work is to model these problems using a representation of the fluid dynamics that is as near to first principles as possible. The algorithm technology developed to effect this consists of four parts: operator-splitting methods, such as predictor-corrector methods and projection methods; adaptive mesh refinement; volume-of-fluid methods; and a hybrid software framework.

The nuclear testing database is unique, irreplaceable, and at risk. Critical information is on perishable media (e.g., films and photography from 1950’s atmospheric test series). Data quality assurance is imperative. This is the last opportunity to involve experimenters who were participants in the atmospheric and underground nuclear test programs in the review of these data. Their insights concerning the merits and limitations of this database must be captured and preserved. For computational aid products, user groups are employed throughout the development process to ensure that products respond to customer requirements.

**(3) Related Federal and Private Sector Efforts.** The DOE organizations responsible for SBSS plan to use their ASCI as a primary mechanism for sustaining nuclear competence. Appropriate levels of DoD customer involvement (e.g., in dual revalidation) are required. The DARE program is leveraging NASA development and coordinating with DOE laboratories and the U.K. Ministry of Defence on content.

### c. *S&T Investment Strategy*

**(1) Technology Demonstrations.** This subarea develops capabilities that support the warfighter support and the systems effects and survivability subareas. No demonstrations are planned within this subarea.

**(2) Technology Development.** The current strategy for nuclear sustainment is predicated, in large part, on the development and use of a new state of the art in advanced computations. The advances being made in modeling of such phenomena as turbulent mixing have direct relevance for both nuclear sustainment and other DoD applications. DARE employs optical media and software engineering to preserve unique nuclear data. Project Graybeard uses experts with experience in test programs to perform quality reviews of data prior to entry into DARE. Computational aids and the EM–1 program use state-of-the-art technologies to provide users with authoritative information in readily usable formats.

**(3) Basic Research**. There are no DoD scientific and operational computing basic research programs.

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