18 Defense Science and Technology

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Introduction

This chapter describes how the Department of Defense (DoD) Science and Technology (S&T) program, first, determines what it must accomplish to meet the needs of the warfighter and, then, implements those goals by developing needed technology. (For more details on the specific goals and the implementation process, I encourage the reader to review the other pieces of Defense S&T documentation: the Joint Warfighting S&T Plan, the Defense Technology Area Plan, the Defense Technology Objectives Document, and the Basic Research Plan.)

Role of Technology in Defense

Technological superiority is a critical component to our national security. In peace, it provides deterrence; in crisis it provides options; in war it provides the edge.

Focusing on Warfighter Needs

Any defense must begin with the warfighter, whose effectiveness is dramatically increased by advanced technology. Our nation relies on the technological superiority of our Armed Forces to maintain our po-

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sition of world leadership. First and foremost, the mission of the Department of Defense Science and Technology program is to ensure that the warfighters today and tomorrow have superior and affordable technology to support their missions, and to provide them with revolutionary war-winning capabilities. To develop a strategy to support that mission we must understand the warfighter's needs and the full range of operations that must be performed by our military.

Fundamental to understanding those needs is an understanding of the strategic environment in which the warfighter operates, now and in the future. This strategic environment includes global U.S. interests (which are political, economic, and humanitarian), a globalized technology, and asymmetric threats. The global spread of advanced technology is transforming the military threats faced by the United States and will challenge our ability to achieve full-spectrum dominance. It is these threats that our technology must address.

Threats

In order to carry out our defense strategy, the U.S. military must be prepared to conduct multiple and concurrent contingency operations worldwide. It must be able to do so in any environment, including one in which an adversary uses asymmetric means such as nuclear, chemical, or biological weapons; information operations; ballistic missiles; or terrorism. These asymmetric threats must be met in any domain—air, land, sea, space, or information.

Future adversaries will increasingly rely on unconventional strategies and tactics to offset the superiority of U.S. forces. Our combat forces must be organized, trained, equipped, and managed with multiple missions in mind. We must be conscious of these threats as we foster technology breakthroughs that will lead to new capabilities to cope with that environment.

Science and Technology Investments

Joint Vision 2010 provides a high-level description of the joint warfighters' needs. A more detailed articulation is presented in the Joint Warfighting Capability Objectives (JWCOs) that form the basis of the Joint Warfighting Science and Technology Plan. The JWCOs cover a broad area of future warfighting capabilities. The Defense S&T program will continue to address each of the JWCOs validated by the Joint Requirements Oversight Council. However, there are crosscutting topics that deserve special priority. The Department will focus a significant portion of its S&T investment in the five areas discussed below.

Information Assurance

Information technology has been a core research area for the Department since the beginning of computing. This research area remains vital, and will be even more significant to the Department as commercially available information technology proliferates. Information superiority is a key enabler for Joint Vision 2010. It is the backbone of the revolution in military affairs (RMA) that will allow U.S. forces to achieve total battlefield dominance.

We are identifying technologies that will address activities related to cyberterrorism and we are developing better protection for critical information systems, both on the battlefield and throughout the nation. We will provide the technology to ensure that our forces can acquire, verify, protect, and assimilate the information needed to effectively neutralize and dominate adversary forces.

Battlespace Awareness

We will continue to find and develop technologies to increase battlespace awareness. The near future will see a proliferation of sensors and associated processors available for battlefield use. Total battlespace situation awareness and understanding, coupled with information assurance, will provide real-time intelligence from "sensor to shooter." Commercial and military space technology and systems will provide major leaps in coverage, timeliness, and resolution. As a result, the amount of raw information available to the battlefield commander and soldier, sailor, airman, and marine is increasing at an ever-expanding rate.

In concept, smart sensor webs will be developed to integrate networks of sensors to provide near-real-time representations of complex battlefield information to the warfighter. The sheer weight of information available to the warfighter will result in the need for technical help in sorting, mining, understanding, and acting on that knowledge. This cognitive readiness will be essential to exploiting battlespace awareness.

Force Protection

Developing the technologies that protect the force, and allowing it to operate wherever needed will be a priority of the Defense S&T program. The 21st century warfighter must have the capabilities to survive, fight, and win in a contaminated environment. The Department's Chemical and Biological Defense program integrates all medical and nonmedical programs and invests in technologies to provide improved capabilities against existing and emerging threats, while minimizing adverse impacts on our warfighting potential. Chemical and biological defense is based on three integrated principles: contamination avoidance, protection, and force sustainment.

The Department has also initiated a technology development program to detect, characterize, and neutralize hardened and deeply buried targets. This focused activity is in response to the emerging threats from nations with underground facilities that protect weapons of mass destruction (WMD) and communication sites. For counterforce applications, automated systems will be developed to accurately process and analyze large volumes of information in near real time. In addition to the identification of hardened and deeply buried targets and timely notification to shooters, improved penetrating munitions will be developed for counterforce missions. Revolutionary new weapon capabilities such as directed energy weapons will receive increased emphasis.

Reduced Cost of Ownership

Because of smaller budgets, the S&T program will provide options to reduce operating and support costs to enable the modernization of our forces. Defense budget reductions have forced an increasing emphasis on affordability as a leading investment factor governing the S&T program. DoD acquisitions will not meet warfighters' needs within current budgets unless we reduce the costs of development, procurement, and life-cycle operation. Since 1989 the Department has dealt with declining budgets by judiciously slowing force modernization in order to concentrate on maintaining force readiness and quality of life. (The budget is discussed in more detail below.)

The Department must now embark on the modernization of our forces to ensure continuing readiness in the 21st century. For this modernization to be possible within our reduced budgets, the Defense S&T program will provide advanced technology that is timely and affordable. Since the cost to own, operate, maintain, and upgrade is greater than the cost of initial acquisition for most systems, full life-cycle costs will be considered during technology development and demonstration. Programs specifically aimed at reducing life-cycle costs will be pursued. (As an example, new propulsion technology holds great promise to reduce the cost of fuel and the per pound cost of launching military payloads into space.) Where appropriate, S&T projects will focus on increasing the effectiveness and decreasing the cost, increasing operational life, and incrementally improving materiel through upgrades.

Maintaining Basic Research

An investment in basic research pays dividends in many ways. Basic research is a long-term investment with emphasis on opportunities for military application far in the future. It also contributes to our national academic and scientific knowledge base by providing approximately 40 percent of the support for all engineering work. The Department sustains its investment in basic research because of proven, significant, long-term benefits to the military, which in turn enhances our national economic security.

Basic research provided the foundation for technological superiority in each of our recent conflicts. Radar made a significant contribution to winning World War II. Stealth, lasers, infrared night vision, and electronics for precision strike played major roles in the Gulf War. Adaptive optics, phased array radar, and global positioning systems (GPS) also contribute to our readiness. Our nation's defense advantage is founded on a wide scope of scientific and engineering knowledge. The Department must continue to invest broadly in defense-relevant scientific fields because it is not possible to predict precisely in which areas the next breakthroughs will occur.

Maintaining basic research has allowed us to keep the technological edge on which our forces have relied. It follows that the way to address future warfighting needs is to invest in broad areas of research that have high potential of yielding revolutionary advances and to pursue solutions to known operational problems.

A successful strategy must foster research that develops new ideas and new innovations. Basic research has given us microsatellites, nanotechnology, biosensors, and the joint strike fighter, among other advances.

We look to basic research to use the advances in information technologies, for example, to enable a revolution in military affairs based on total battlespace situation awareness and information assurance.

Enabling Capabilities

New military capability and operational concepts emerge from many different sources. Historically, the Defense S&T program has responded to the known needs for military capability (that is, enabling capability) and encouraged the development of totally new operational concepts and capabilities (that is, revolutionary capabilities).

Enabling capabilities include software intensive systems, high performance computing, and modeling and simulation. These capabilities support research that includes simulating high-energy rocket fuels, designing armor and projectiles, supporting aircraft weapon release capability and integration, predicting radar cross-sections and forecasting ocean waves.

Propulsion is another enabling capability and has three major initiatives:

- the Integrated High Performance Turbine Engine Technology Program, with a goal of doubling engine performance by 2005 and increasing affordability by a power of ten by 2017,

- the Integrated High Payoff Rocket Propulsion Technology Program, with a goal of doubling rocket propulsion system capabilities by 2010 (using a baseline of the space shuttle main engine circa 1993), and

- the Hypersonic Technology Program, with a goal of demonstrating a hydrocarbon-fueled scramjet at M=8 by 2002 (there is no baseline since this is a new capability).

Revolutionary Capabilities

An example of revolutionary capability is high-energy lasers. Research areas here include chemical lasers, solid-state lasers, free-electron lasers, beam control, lethality/vulnerability, and advanced technologies. Another revolutionary capability is electric drive technology. For naval platforms, this will allow increasing fuel savings; developing technology for reducing the number of personnel; and designing an enabler for high-powered weapons, sensors, catapults, and other devices. For ground vehicles, electric drive research includes developing technology for lightweight, deployable vehicles; increasing fuel efficiency; and power conditioning for multiple new capabilities (survivability, directed energy and high-powered microwave weaponry, dynamic armor, and composite materials). Air Force platforms benefit from electric drive through reducing maintenance and life-cycle costs, increasing power system reliability by four times, and reducing vulnerability.

A third example of revolutionary capability is autonomous systems. Research issues here include cooperative localization, communication for strategy and shared sensing, real-time modeling of adversaries, real-time multirobot continuous planning, and multirobot control learning.

Implementation

Reliance

The Defense S&T Reliance process includes a coordinating body that helps eliminate unnecessary duplication and seeks out opportunities for synergy, integrating the various component programs into a corporate S&T program. Reliance enables the DoD S&T community to work together to enhance S&T's role in supporting the Department's acquisition programs as well as the warfighters. The Reliance planning process is overseen by the Defense S&T Advisory Group chaired by the Deputy Under Secretary of Defense (Science and Technology). Reliance is responsible for preparing the Joint Warfighting Science and Technology Plan, the Defense Technology Area Plan, and the Basic Research Plan. (These three documents are often referred to as the Defense S&T Plans.) The Department will continue to use the Defense S&T Reliance process to coordinate and integrate the Departments S&T efforts.

High Quality S&T Infrastructure

Declining defense budgets have forced reductions of laboratory infrastructure, both in facilities and personnel. This has added risk to the Department's ability to innovate in the long term and respond to new warfighter requirements in the short term. As DoD laboratories become smaller, we must emphasize ensuring the excellence of the people, the facilities they work in, and the equipment they use. Within its capabilities and authorities, the Department will continue to pursue initiatives to recruit and retain top scientists and engineers and to maintain and operate modern facilities.

Joint Experimentation at U.S. Joint Forces Command

The Secretary of Defense has assigned to the Commander in Chief, U.S. Joint Forces Command (USJFCOM), the responsibility for conducting Joint Experimentation. USJFCOM will use the Joint Warfighting Science and Technology Plan as a primary source for identifying technological capabilities to be incorporated into concept development and experimentation activities. Feedback from Joint Experimentation will influence where emphasis will be placed in the Defense S&T program.

Technology Transition

Our Cold War acquisition process, while very successful at producing highly effective military systems used in the Gulf War, needs streamlining. We must reduce development time and acquisition costs for fielding critical technology to rapidly meet warfighter needs and remain viable in a constrained resource environment. Increasingly, advanced technology is becoming available on international markets, requiring DoD to accelerate the development process as never before. Rapidly transitioning technology from S&T to an operational capability is crucial. To speed up the technology transition process, three important mechanisms, Advanced Concept Technology Demonstrations (ACTDs), Advanced Technology Demonstrations (ATDs), and Joint Experiments, have been established to ensure the transition of innovative concepts and superior technology to the warfighter and acquisition customer both faster and less expensively. ACTDs are a key element in the S&T program. They are needed to determine the military utility of proven technologies, to expedite technology transition, to provide a sound basis for acquisition decisions, and to develop the concept of operations that will optimize effectiveness. They cover all technologies and provide rapid capability to the warfighter.

Funding

In order to maintain and increase technological superiority and ensure rapid technology transition we must have adequate funding. Figure 1 shows funding that supports technology transition programs. Funding from Dual Use Science and Technology (DUS&T) supports the development of the initial product/process capability through the early phases of insertion. Small business funding plays a role shortly after the beginning and continues into the early phases of product/process improvement and sustainment. Funding from manufacturing technology comes in during the product/process development phase. Independent research and development funding underpins the entire process.

The DoD budget for science and technology has been increasing since FY 1997, as Figure 2 shows (in constant FY 2000 dollars). We expect budget requests to increase, along with the appropriation. Since 1997, the appropriation has exceeded the President's budget request. However, we do not expect to match in the near future the high appropriation achieved in 1993.

Figure 1
Technology Transition Programs

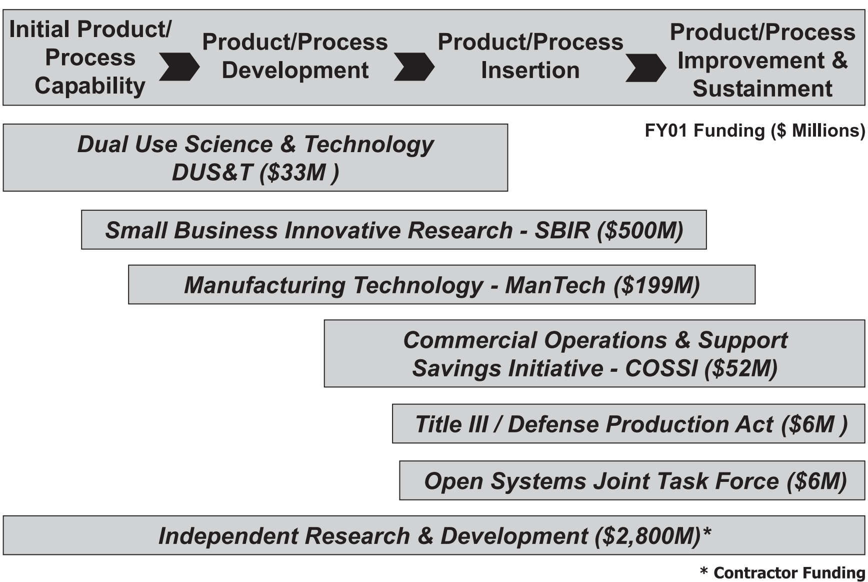


Figure 2
Department of Defense Science & Technology (S&T)

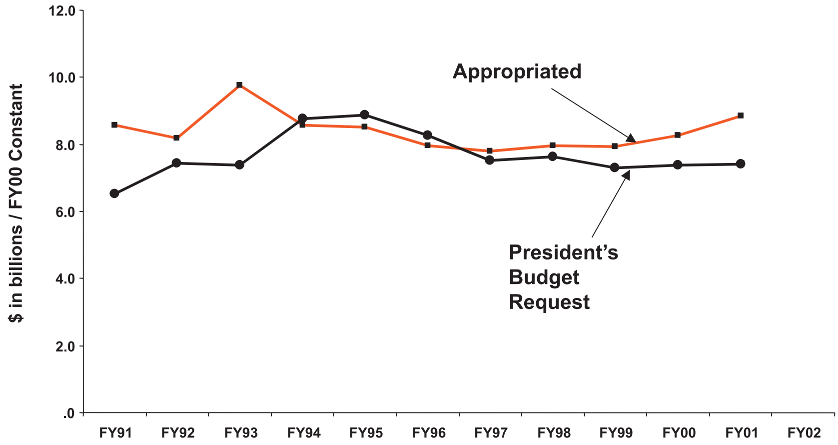


Figure 3 breaks down the budget by Service. The Air Force was the largest investor in S&T a decade ago; today they are the lowest investor in S&T.

Figure 4 breaks down the DoD S&T investment for FY 2001 for each Service by basic research, applied research, and advanced technology development. The Navy is the largest investor in basic research. The Defense Advanced Research Projects Agency (DARPA) has the largest investment in applied research. DARPA and the Army have about the same investment in advanced technology development.

Figure 5 shows the recipients of DoD S&T funds. For basic research, universities receive the most funding. For both applied research and advanced development, industry receives the most. Other recipients are in-house labs, nonprofit institutions, state and local government facilities, and foreign institutions.

Figure 6 shows technology perspectives for today's force, the next force, and the force after that. It uses the FY 2001 budget numbers. The Services are concerned with readiness for today's force, modernization for the next force, and future technology for the force after that. Navy and Air Force spend a higher percent of their budgets on modernization than the Army does. Most of the Army's resources are spent on

Figure 3
Service Investment in Science & Technology

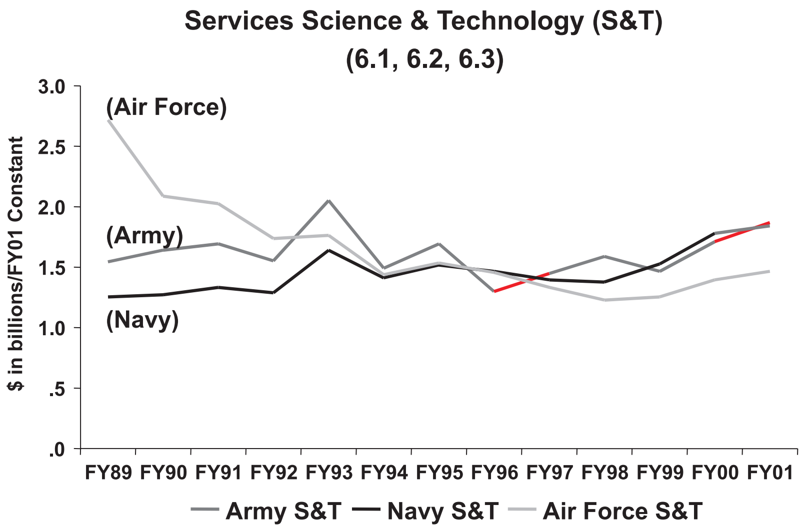


Figure 4
DoD S&T Investment

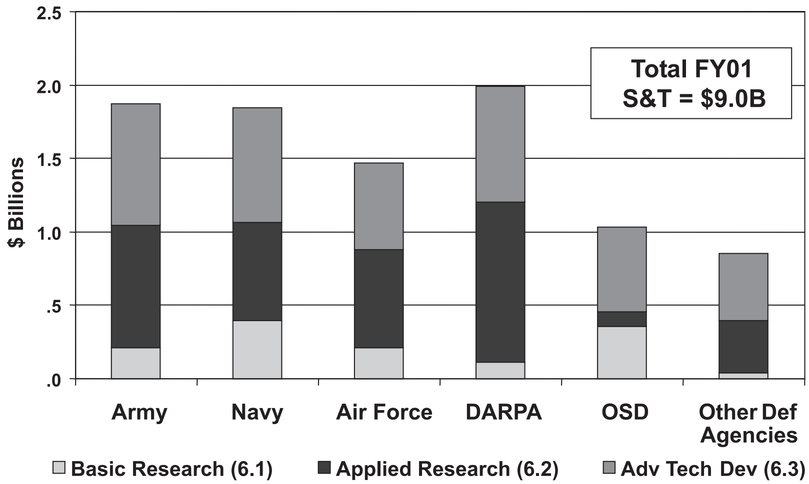
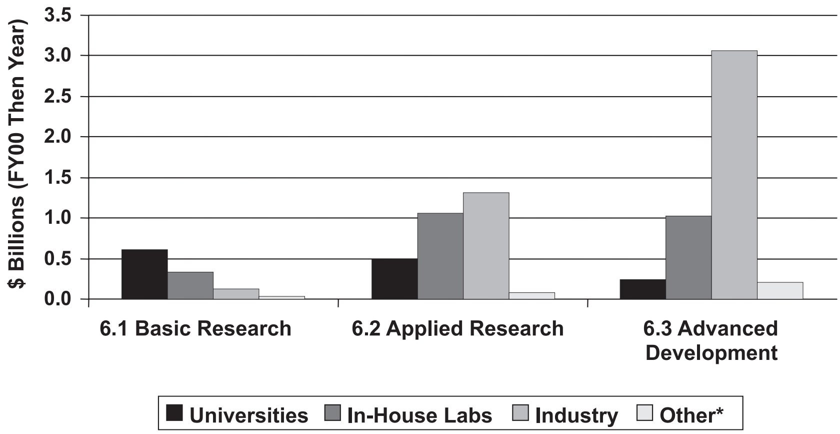


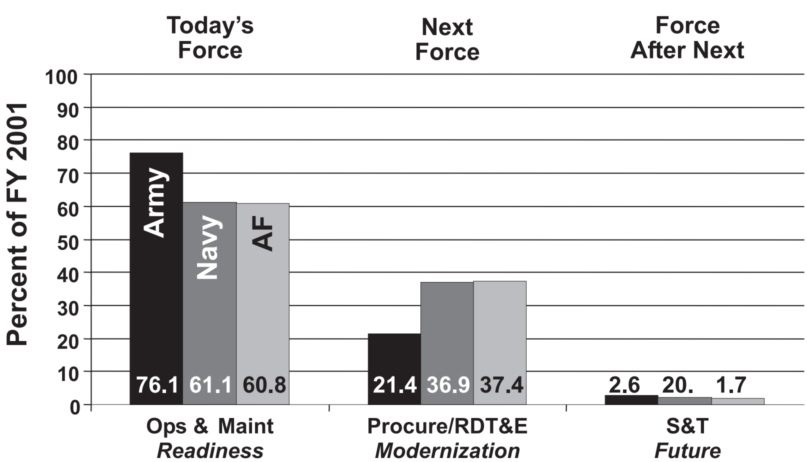
Figure 5
Recipients of DoD S&T Funds



**Includes non-profit institutions, State and local government, and foreign institutions.*

Source: NSF Report, *Volume 48 (FY 2000)*

Figure 6
Technology Perspectives FY 01



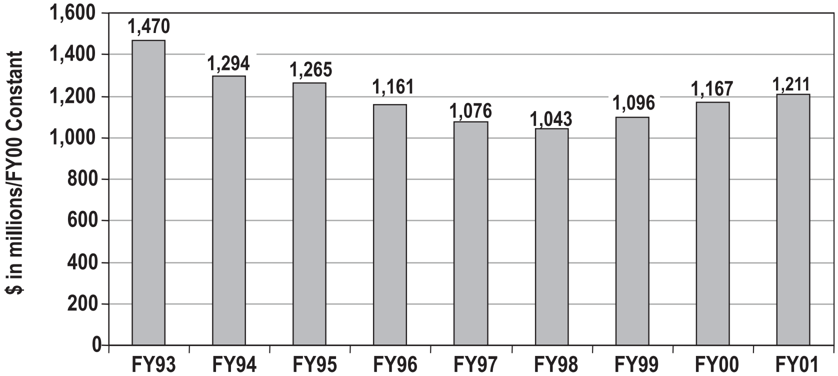
readiness. But the Army spends a higher percentage than the other Services on the future. This figure demonstrates how small the investment in S&T is overall—and the importance of protecting it.

Figure 7 shows the funding stability in basic research from FY 1993 to FY 2001. The dollars shown are constant FY 2000 dollars. Note that basic research funding is down over $250 million (about 20 percent) in purchasing power since 1993. Funding stability in basic research is important because it supports most of the federally funded university research in several key disciplines. It supports 70 percent of electrical engineers, 65 percent of mechanical engineers, and 45 percent of metallurgical engineers and computer scientists. New discovery takes time, so stable funding is key for innovation. A stable funding base also helps to develop the next generation of scientists and engineers.

Beyond the Department of Defense

In an age of budget challenges and exploding technology, DoD cannot operate in seclusion. The Department has to make effective use of all available resources. Private industry, outside labs, and a variety of partners all help enhance the DoD mission.

Figure 7
Funding Stability in Research



Leveraging the Technology Explosion

Increasingly, many defense needs can be met by leveraging the commercial technology explosion and utilizing commercial products such as computers, software, electronics, and communications. As military capability moves toward information-based warfare, and the information age continues to experience a technology explosion in the civilian economy, there will be an abundance of opportunities to leverage commercial technologies and products for military use. The Department will monitor commercial technology and product developments and adopt or leverage such offerings when they show promise of enhancing military capability. The Department will bring together the warfighters, DoD planners, scientists, and engineers to explore ways to take advantage of the opportunities offered by rapid commercial technology advancements.

Even in areas when applicable, the commercial technology explosion will not by itself satisfy our warfighters' needs. Many of these needs are exclusively military and there is no commercial technology that addresses them. Other warfighter needs have elements in common with commercial technology, but are driven by military requirements. The challenge for the defense science and technology community will be to choose what technology to leverage and what technologies we must develop with only our own investments.

Requirements for World-Class Laboratories

The nation's technical superiority depends on world-class laboratories. These laboratories need outstanding people. So the nation's S&T workforce is a critical component of any research and development. We also need visionary leadership and state-of-the-art facilities. From these will come the challenging problems that give birth to new technologies.

Partnerships

The strength of the Defense S&T program depends directly on the health of its partners. These partners together provide the environment that supports the needs of the warfighter. Each partner plays a vital role. Universities provide new ideas and knowledge, Service laboratories provide stability and ties to the operational forces, and DARPA is committed to high-risk, high-payoff programs. Other agencies allow us to leverage our combined resources. Industry provides innovation and transition of technology. Our international allies for joint research programs address interoperability from the beginning. Our S&T program is stronger because of these partnerships, each of which brings something unique to the solution of national security problems.

Summary

In peace, technological superiority is a key element of deterrence. In crisis, it provides a wide spectrum of options to the national command authorities and commanders in chief, while providing confidence to our allies. In war, it provides an edge that enhances combat effectiveness, reduces casualties, and minimizes equipment loss. In view of declining defense budgets and personnel reductions, advancing affordable military technology and ensuring that it undergoes rapid transition to the warfighter are critical national security obligations.