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## PREFACE

This study was supported as an Independent Research Project by the Institute for Defense Analyses to provide a perspective on how changes in the economic and technological arena—often referred to under the rubric "globalization"—bear upon the Department of Defense's approach to conducting and managing its research and development. The study draws upon and expands earlier work supported by the Defense Advanced Research Projects Agency (DARPA) and the Missile Defense Agency (MDA), cited in the paper.

The authors wish to acknowledge the contributions of former Secretary of Defense, Dr. William J. Perry and former Director Defense Research and Engineering, Dr. John S. Foster, who helped clarify aspects of DoD's R&D management in earlier years, the thoughtful review comments of former Under Secretary of Defense (Acquisition and Technology) Dr. Paul G. Kaminski and former Deputy Director, Defense Advanced Research Project Agency Robert A. Moore, and the inputs of Dr. John Frasier, Dr. John Transue, and Dr. Jay Mandelbaum of IDA who provided suggestions and review comments throughout the study. In addition, we wish to thank Mr. Philip Major, Vice President—Programs, Mr. Michael Leonard, Director, Strategy, Forces, and Resources Division, and Dr. Michael Rigdon, Director, Science and Technology Division, for their support of this effort.

## CONTENTS

## EXECUTIVE SUMMARY

Since the creation of the Department of Defense (DoD) in 1947, its approaches for managing, supporting, and harnessing science and technology (S&T) for military needs have changed episodically in response to changes in the nature of perceived threats, the rise of economic and technical challengers to the US, and the priorities of different administrations and DoD leaders. Today's global dispersion of technology capabilities and the changing threat spectrum call for another such adjustment if DoD is to maintain its leadership in the application of S&T to meet defense needs.

DoD's S&T management approach since the mid-1980s has been dispersed and decentralized. The Office of the Secretary of Defense (OSD) has performed mostly coordination and oversight as opposed to the high-level direction, including programmatic management of high-priority technologies, which was characteristic in the 1960s and 1970s. OSD efforts during the end of the Cold War era fostered a "revolution in military affairs" that conferred fundamental advantages to the US military. These capabilities became the basis for the overwhelming forces that performed so astonishingly well in Desert Storm, and in Operation Enduring Freedom, and Operation Iraqi Freedom.

The world has changed dramatically since these systems were developed. The economic and technical factors that DoD relied upon to achieve today's dominant capabilities were indigenous: US universities and US industrial firms dominated their markets and performed R&D; products were developed and produced domestically. Beginning in the 1980s, European and especially Asian firms began to challenge US firms in such areas as telecommunications, heavy manufacturing, information processing, and microelectronics. By the 1990s, a global economic structure has unfolded in which high technology firms engaged in R&D and production throughout the world via their own subsidiaries and in partnership with other firms. Even US universities found that they were being matched by the growing technical competence of foreign research institutions.

During the same period, the threat spectrum facing the US and its allies also changed dramatically. Today, the US faces threats from dispersed, "asymmetric" adversaries with potential access to catastrophic attack capabilities. This puts a premium on rapidly developing and fielding technologies for finding, locating, and negating these often-elusive adversaries, and their capabilities, before they can strike. Moreover, the global economy has come to include the defense industry, resulting in advanced defense technologies and systems becoming increasingly available to regional and potential future peer adversaries, shrinking the US advantage.

Sustaining dominant military technical capabilities in the future requires a fundamental re-examination and alteration of DoD's technology innovation processes, as the changes in the global technological and economic scene have eroded the very basis by which DoD achieved its technological superiority. This global diffusion of capabilities in emerging technologies raises serious questions as to how those technologies with implications for advanced military capabilities can be identified, supported, accessed, and employed by DoD to maintain its position of technological superiority. The S&T practices of DoD today need to be responsive to this emergent environment.

The type of challenge facing DoD is similar, but on a much larger scale, to that faced by leading U.S. high-tech firms over the past two decades, which led many to fundamentally redefine their technology development processes, as discussed in the second section of this paper. DoD needs to adopt similar changes in strategic technology management to realize its military-technological objectives in the unfolding technical-economic-security environment. Toward that end, this study discusses:

- Lessons learned from past DoD S&T management efforts and initiatives, especially those within the Office of the Secretary of Defense (OSD)
- How industry has coped with globalized competitive threats and the explosion of new technologies, with a focus on the roles and functions of Chief Technology Officers (CTOs) in various commercial contexts
- The relevance of past DoD experience and modern industrial best practices with respect to the adequacy and appropriateness of current DoD strategic S&T management capabilities, mechanisms, and processes.

## TOWARD A FOCUSED DEFENSE INVESTMENT STRATEGY TO MEET THE CHALLENGES OF THE GLOBAL TECHNOLOGY ENVIRONMENT

Reflecting on the new environment of global technology DoD needs to focus on five fundamental elements of an investment strategy for the future.

### 1. Investing in basic technologies that can lead to fundamental technical advantages

*Reformulating approaches for S&T investment in the current world environment may be one of the most significant issues facing DoD and the country in the coming years.*

**2. Building communities of change-state advocates**

*With the internationalization of science and technology in academia and in commercial industry, DoD will be increasingly challenged to build and maintain access to the leading sources of technological know-how.*

**3. Defining strategic challenges in detail across multiple scenarios**

*Establishing an integrated approach employing such assessment capabilities to guide and integrate DoD's technology development priorities would be a useful means to come to grips with the complexities of the future security environment.*

**4. Developing disruptive systems concepts and testing promising disruptive concepts through large-scale, integrated demonstrations**

*Transitioning potentially "transformational" military capabilities from R&D into acquisition remains a major challenge. OSD needs to continue to provide both leadership and creativity in fostering "bridging" mechanisms for moving innovative concepts and technologies into application and acquisition.*

**5. Providing a clear, top-level imprimatur for risk reduction and acquisition of specific capabilities**

*A strong leadership role in OSD—a position akin to the CTO of a high-tech firm—for defining, guiding and supporting the processes to further the development and transition of such new technological capabilities is required.*

## CONCLUSIONS

While a full prescription and implementation plan for appropriate DoD strategic S&T management in the face of these challenges is beyond the scope of this paper, the following are prerequisites for successfully formulating and implementing a technology development strategy responsive to the challenges of the future:

- A "CTO-like" officer in DoD with a direct and close working relationship with the SECDEF and DEPSECDEF, who has the authority, imprimatur and resources (including personnel) for [1] assessing the emerging security and technology environment and [2] providing a top-down strategic perspective and explicit guidance on the needed technology direction and priorities to be responsive to this environment and its attendant uncertainties.
- A capable, trusted staff with detailed technical competency in technologies that are known to be important for existing or planned systems ("core technologies") and resources to explore emerging technologies whose national security significance is not yet clear.
- Direct contact with Joint Staff, COCOMs, and Components to understand needs and to formulate means to experiment with and rapidly deploy initial operational capabilities to meet emergent needs
- Support, authorities, and resources from Congress.

# I. INTRODUCTION AND OVERVIEW

Since the creation of the Department of Defense (DoD) in 1947, its approaches for managing, supporting and harnessing science and technology (S&T) for military needs have changed episodically in response to changes in the nature of perceived threats, the rise of economic and technical challengers to the US, and the priorities of different administrations and DoD leaders. Today's global dispersion of technology capabilities and changing threat spectrum call for another such change if DoD is to maintain its leadership in the application of S&T to meet defense needs.

DoD's S&T management approach since the mid-1980s has been dispersed and decentralized. The Office of the Secretary of Defense (OSD) has performed mostly coordination and oversight as opposed to the high-level direction, including programmatic management of high priority technologies, which was characteristic in the 1960s and 1970s. OSD efforts during the end of the Cold War era—driving a number of change-state technological developments, such as stealth, stand-off precision strike, and advanced tactical intelligence, surveillance and reconnaissance systems—fostered a "revolution in military affairs" that conferred fundamental advantages to the US military.[1] These capabilities became the basis for the overwhelming forces that performed so astonishingly well in Desert Storm, Operation Enduring Freedom and Operation Iraqi Freedom.

The world has changed dramatically since these systems were developed. The economic and technical factors that DoD relied upon to achieve today's dominant capabilities were indigenous: US universities and US industrial firms that dominated their markets and performed R&D, product development and production domestically. Beginning in the 1980s, European and especially Asian firms began to challenge US firms in such areas as telecommunications, heavy manufacturing, information processing, and microelectronics. By the 1990s, there was growing "off-shoring" and "outsourcing" of both production and technology development, as foreign competitors grew increasingly prosperous and technically competent and as information technology spread globally to provide the ability to access technical and production resources worldwide. A global economic structure has unfolded in which high technology firms engage in R&D

[1] Richard Van Atta, Michael Lippitz, Jasper Lupo, Rob Mahoney, Jack Nunn, *Transformation and Transition: DARPA's Role in Fostering an Emerging Revolution in Military Affairs*, Volume I – Overall Assessment, Alexandria, VA: Institute for Defense analyses, IDA Paper P-3698, April 2003.

and production throughout the world via their own subsidiaries and in partnership with other firms. Even US universities are finding that they are being matched today by growing technical competence of foreign research institutions.

During the same period, the threat spectrum facing the US and its allies also changed dramatically. The Soviet conventional threat, while multifaceted, was comprehensible in familiar warfighting terms. Today, the US faces threats from dispersed, "asymmetric" adversaries with potential access to catastrophic attack capabilities. This puts a premium on radically new intelligence capabilities and rapidly developing and fielding technologies for finding, locating and negating these often-elusive adversaries and their capabilities before they can strike. Moreover, the global economy has come to include defense industry, resulting in advanced defense technologies and systems becoming increasingly available to regional and potential future peer adversaries, shrinking the US advantage.[2]

Sustaining dominant military technical capabilities in the future requires a fundamental re-examination and alteration of DoD's technology innovation processes, as the changes in the global technological and economic scene have invalidated the very basis by which the DoD had achieved technological superiority. The global diffusion of capabilities in emerging technologies raises serious issues as to how those technologies with implications for advanced military capabilities can be identified, supported, accessed, and employed by the DoD to maintain DoD's position of technological superiority. The S&T practices of DoD today are largely unresponsive to this emergent environment.

The type of challenge facing DoD is similar, but on a much larger scale, to that faced by leading US high-tech firms over the past two decades, which led many to fundamentally redefine their technology development processes (discussed in the second section of this paper). DoD needs to adopt similar changes in strategic technology management to realize its military-technological objectives in the unfolding technical-economic-security environment. Toward that end, this study discusses:

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[2] Richard A. Bitzinger, "Globalization in the Post–Cold War Defense Industry: Challenges and Opportunities," in Ann R. Markusen and Sean S. Costigan (eds.), *Arming the Future: A Defense Industry for the 21st Century*, New York: Council on Foreign Relations Press, 1999. See also Andrew Hull and David Markov, "Trends in the Arms Market," *Jane's Intelligence Review*, Part 1 and Part 2, April 1997 and May 1997.

- Lessons learned from past DoD S&T management efforts and initiatives, especially those within OSD.
- How industry has coped with globalized competitive threats and the explosion of new technologies, with a focus on the roles and functions of Chief Technology Officers (CTOs) in various commercial contexts.
- The relevance of past DoD experience and modern industrial best practices with respect to the adequacy and appropriateness of current DoD strategic S&T management capabilities, mechanisms, and processes.

## II. BRIEF HISTORY OF DOD S&T LEADERSHIP: RELATIONSHIPS AND INITIATIVES

With the US at the height of its relative military and economic power in the years just after World War II (WWII), the recognition that the Soviet Union was a strategic threat and an implacable adversary led to massive research and development efforts in several areas: nuclear weapons and delivery systems, air and missile defense, and electronics, among others. In 1958, in the wake of the Soviet launch of Sputnik, Congress established the Director of Defense Research and Engineering (DDR&E) as the principal science and technology advisor to the Secretary of Defense (SECDEF) with the authority to manage Service S&T budgets in detail and report directly to Congress. The Advanced Research Projects Agency (ARPA) also was created in 1958, with a mission to foster advanced technologies and systems that would create "revolutionary" advantages for the US military, particularly concepts that were not being pursued by the military Services.[3]

After a decade in which the role and structure of the DDR&E organization remained relatively fixed, the second decade saw major perturbations. In 1977, in view of the increasing technology content of US defense systems, the DDR&E was replaced by the Under Secretary of Defense (USD) for Research and Engineering, with acquisition issues added to what had been the DDR&E portfolio. But, in the early 1980s, the USD(R&E) lost acquisition management, and its central control of defense research and engineering diminished. Underlying these changes was a fundamental change in management philosophy, which Secretary of Defense Weinberger initiated, that gave the military Services much greater sway relative to OSD. In particular, OSD took on a diminished role in directing and overseeing S&T programs, a major swing from the initial role of the DDR&E when it was established. In 1986, the Goldwater-Nichols Act established an overarching Under Secretary for Acquisition, USD(A), and re-established the position of the DDR&E subordinate to it. Since that time, the USD(A) has had its name and charter expanded as the USD(Acquisition, Technology and Logistics).

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[3] Herbert F. York, *Making Weapons, Talking Peace*, New York: Basic Books, 1987, pp 128-171.

The creation of the DDR&E in 1958 reflected a broad recognition of the need for central, strategic DoD S&T management. Disparate, decentralized, and often competitive efforts by the military Services were seen as inefficient, resulting in the perceived Soviet lead in space and ballistic missile technology. Prior to the 1958 DoD Reorganization Act, the Office of the SECDEF had little statutory authority or organizational power to focus US military S&T efforts.

Herbert York, the first DDR&E, a brilliant scientist and the first director of the Livermore (Lawrence) Laboratory, built up the Office's capabilities to provide intellectual leadership, which he viewed as critical for it to execute its oversight role and so that "radical changes (could) be accomplished." He did this by creating new "assistant directors" with responsibilities defined by problem areas—strategic warfare, tactical warfare, air/missile defense, naval systems, and intelligence—and then recruiting talent from the aerospace and electronics industries to fill the new positions. (Prior to this reorganization, OSD technology oversight had been organized by technology area and managed by career civil servants.)[4]

The 1958 DoD Reorganization Act also created ARPA as DoD's corporate research activity, reporting directly to the SECDEF, with the flexibility to move rapidly into new areas and explore opportunities that held the potential of "changing the business"—particularly radical, long-term S&T in areas not being pursued by the military Services. ARPA undertook a portfolio of R&D projects at different levels of risk and of different scale in a large variety of technical fields, mostly through seeding and coordinating external research communities and funding large-scale demonstrations of disruptive concepts.[5] ARPA's initial focus was on three Presidential Initiatives—space, missile defense, and nuclear test detection—but it also initiated research efforts in areas such as computer science, behavioral science, and materials as part of its broader charter to prevent future surprises like Sputnik.[6]

With Harold Brown (also from Livermore) succeeding York as DDR&E in 1961, the essential structure, functioning, and focus of the office was maintained. The next DDR&E, John S. Foster, also from the Livermore Lab, took Brown's place in 1966, after

[4] Ibid., pp 166-171.

[5] DARPA did not and does not perform research directly but rather conceives and finances projects, serving as an active broker among technology, military, and occasionally policy communities.

[6] Richard H. Van Atta, Seymour J. Deitchman, Sidney G. Reed, *An Overall Perspective and Assessment of the Technical Accomplishments of the Defense Advanced Research Projects Agency: 1958-1990*, DARPA Technical Accomplishments, Volume III, Alexandria, VA: Institute for Defense Analyses, IDA Paper P-2538, July 1991.

having turned the position down more than once. However, earlier, when visiting Brown in the Pentagon, he mentioned that he felt that OSD ought to be pushing a lot more R&D efforts for supporting the US effort in Viet Nam. Brown and Foster met with SECDEF McNamara, and Foster asked McNamara, "What do you think we should be doing in R&D for Viet Nam?" When the Secretary responded with a long list of needs, Foster felt that he had no choice but to take the position—and stayed on for eight years.[7] With this charter, he pushed the DDR&E staff and ARPA to stress technologies for tactical applications (such as night vision, the first smart weapon—a TV guided bomb; laser guided weapons, distributed sensors, C-130 gunship, A-10 close air support aircraft, GPS, DSP satellites) and to be more aggressive in transferring technologies to the Services. Another key role the DDR&E played was as the "voice of the customer" for intelligence technologies—providing a technically competent advocacy for new capabilities that the intel community was not providing.[8]

From the outset, while ARPA formally reported directly to the SECDEF, its programs also fell under the cognizance of the DDR&E. As York states, "On behalf of the Secretary, I "approved, disapproved, or modified" all ARPA projects in exactly the same way that I did those of the three military Services."[9] Moreover, the DDR&Es, from York through William Perry in 1976, all specifically designated the Director of ARPA (with SECDEF approval).

To affect his focus in ARPA, Foster brought in Eberhart Rechtin as Director. By transferring missile defense programs to the Services and several basic science programs to the NSF, ARPA's budget was cut almost in half within two years. Rechtin's successor, Steven Lukasik, continued on this path, with a focus on building relationships between ARPA and the operating commands, the Joint Chiefs of Staff, US allies, and forward-thinking officers who could become "customers" for ARPA projects.[10]

In the early 1970s, as the US began to disengage from Viet Nam, national security leadership refocused attention on the Soviet Union. The Soviet build-up of

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[7] Telephone interview with Dr. John Foster, February 10, 2005.

[8] Foster, telephone interview, May 9, 2005.

[9] York, p. 169.

[10] Stephen Lukasik, interview, July 24, 2001. Nicolas Lemann put it well in "Dreaming about War" (*The New Yorker*, July 16, 2001, p. 37): "Big changes many times happen... where only a small part of the force is really changed… because, within the officer corps, there is a subgroup that thinks that the available technology can be used in some novel way, and it's either supported enough by the top people or somehow or another gets allowed to be tried. And then comes the war, and real combat that shows that, by God, these guys were right—that this is the thing that really works."

intercontinental nuclear forces and the increasing effectiveness of their integrated anti-aircraft systems diminished the credibility of US and Western European plans to use theater nuclear weapons and superior tactical aviation to counter the Soviet Union and its Warsaw Pact allies' advantages in conventional forces. It was not deemed practical to increase military procurement and the size of the armed forces to match Warsaw Pact numbers. Instead, DARPA[11] (under Lukasic) and the Defense Nuclear Agency jointly funded the Long Range Research and Development Planning Program to "broaden the spectrum of strategic alternatives" available to the President and the Secretary of Defense against "limited Soviet aggression."[12]

As part of the program, various panels and contractors considered integrated nuclear and conventional concepts, technologies, systems, and doctrine to meet a variety of military contingencies. Over time, these converged around various new defense concepts that emphasized *standoff precision strike*. The problem of standoff precision strike was further defined in terms of the "integration of a wide range of technologies: target detection, recognition and location; delivery vehicles and munitions; and weapon navigation and guidance. This dictate(d) a unified approach to development in these areas and the establishment of operational procedures for effective integration and employment of both targeting and weapons systems."[13] Underlying many of these technologies was the emergence of microelectronics as an enabler of sensing and processing capabilities for precision strike. Leading defense analysts such as Albert Wohlstetter, Joseph Braddock, Andrew Marshall, Donald Hicks, and Fred Wikner promoted these concepts throughout the defense community and to top OSD and Service leadership.

In 1973, Foster was succeeded by Malcolm Currie, Director of Hughes' corporate research laboratory, who was the first DDR&E whose background was primarily in electronics rather than nuclear weapons. Coming from a corporate lab, he knew that to be productive OSD would require Service cooperation. To this end, Currie called a retreat with the Assistant Secretaries for R&D for all the Services, and they developed "operational principles" among themselves. These relationships were maintained over a series of lunch meetings, every 3-4 weeks, and, through these connections, Currie built

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[11] The name was changed by DoD Directive from ARPA to DARPA, for *Defense* Advanced Research Projects Agency, in 1972. In 1993, the name was changed back to ARPA, and then in 1996, it was changed again to DARPA by the 1996 Defense Authorization Act.

[12] Final Report of the Advanced Technology Panel, *ARPA/DNA Long Range Research and Development Planning Program*, April 30, 1975, pp. 1–2; and Minutes of the First Meeting of the Advanced Technology Panel, August 31, 1973.

[13] Final Report of the Advanced Technology Panel, *ARPA/DNA Long Range R&D Planning*, p. 6.

relationships with the Service Chiefs and Service Secretaries. But he did not depend on relationships alone. He also used the authorities of his office, when necessary, to bring the Services into line or to push new concepts. Currie noted that the office directors and staff he inherited from the prior DDR&Es, derived from York's initial recruiting, were a "dream team" of proficient technologists and were highly qualified to perform detailed program reviews of Service programs in order to resolve technical, cost, and management issues.[14] They were also people with "a good understanding of what the problems were… and could think out of the box."[15]

Currie appointed George Heilmeier from the DDR&E staff as DARPA Director and gave him a mandate to refocus DARPA on "basic research and big projects that could make a difference."[16] A particular concern for Currie, based on guidance from Secretary of Defense Schlesinger, was the need to harness emerging technology capabilities to address the challenge of Soviet military buildup. Heilmeier saw the need for large-scale, expensive demonstrations as proof-of-concept demonstrations of integrated capabilities and conceived a new program category in order to protect the rest of DARPA funding should they run into difficulties or be cut by Congress. Currie and Heilmeier promoted greater "customer pull" by pushing DARPA program managers to secure some form of Service commitment and, in some cases, actual funding contributions for their programs.

Currie recommended to incoming Secretary of Defense Harold Brown that William J. Perry be his replacement. (Much of the DDR&E staff and Heilmeier at DARPA remained, providing continuity.) Brown picked Perry, in part because he wanted an "IT person" in the slot. Also, because of his concerns with the problems of "handoff" from R&D into acquisition by the Services, Brown wanted someone who could deal with production and logistics; i.e., someone who had run a business.[17] This was Brown's explicit rationale for transforming the DDR&E position into the Under Secretary of

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[14] Malcolm Currie, interviewed by R. Van Atta and M. Lippitz, Newark, NJ, July 11, 2001.

[15] George Heilmeier, interviewed by R. Van Atta and M. Lippitz, Dallas, TX, July 13, 2001.

[16] Heilmeier promulgated a set of guideline questions—the "Heilmeier catechism"—which are still applied today for DARPA program management: What are you trying to accomplish? How is it done now, and with what limitations? What is truly new in your approach which will remove current limitations and improve performance? By how much? If successful, what difference will it make? What are the mid-term, final exams, or full-scale applications required to prove your hypothesis? When will they be done? What is the DARPA exit strategy? How much will it cost? (Excerpted from DARPA presentation). See also "1993 Tech Leader Dr. George H. Heilmeier: President and CEO, Bellcore, Livingston, N.J.,"), *Industry Week*, December 20, 1993.

[17] William J. Perry, interviewed by R. Van Atta and M. Lippitz, Stanford, CA, July 26, 2002.

Defense (Research and Engineering) in 1977, expanding the portfolio to include acquisition.[18]

Brown made it clear that he wanted Perry to help him "deal with the Soviets."[19] Heilmeier briefed Perry in detail on the technology thrusts he and Currie had begun at DARPA in 1975. Perry—whose background was also in defense electronics, particularly surveillance systems—perceived that the combat effectiveness of NATO forces could be substantially multiplied by exploiting these technologies. However, he also determined that, given their revolutionary nature, implementation of these technologies as military capabilities would require a concerted, focused management effort directed by his office.

Brown and Perry began by elevating what had been a technology strategy under Currie to the level of a broad defense strategy, which they labeled the "Offset Strategy."[20] Its central idea was that synergistic application of improved technologies—electronic countermeasures, command and control, stealth, embedded computers, and precision guidance—would allow the US to overcome Soviet defenses and destroy Soviet massed tanks before they could overrun Western Europe. Then, with the Offset Strategy as a guide and the Secretary of Defense's imprimatur, Perry focused the attention and support of high-level DoD decision makers, Service chiefs, and Congress to speed several important capabilities from concept to implementation. Perry set up special executive review panels for the high priority programs, which he chaired. Program managers were instructed to highlight problems with Service delays and with technology, which Perry would handle personally. (After a few such interventions, there was much less Service obstruction.)[21] Also, between 1977 and 1981, DARPA's budget almost doubled.

When the Reagan Administration took office in 1981 and Caspar Weinberger became Secretary of Defense, there was a major shift in the role of OSD in general, and the US(DR&E) in particular. Perry's successor as US(DR&E), Richard DeLauer, enjoyed much less support from SECDEF Weinberger, who favored Service management of S&T programs. Weinberger instituted management and organizational changes toward more decentralized program execution. He strengthened the role of the Service Secretaries, including seating them on the Defense Resources Board, an advisory group on major resource decisions, and having them report directly to him on the performance of major

[18] William J. Perry, interviewed by R. Van Atta, Stanford, CA, March 23, 2005.

[19] William J. Perry, interviewed by R. Van Atta and M. Lippitz, Stanford, CA, June 6, 2001.

[20] Charles Lane, "Perry's Parry: Reading the Defense Secretary's Mind," *The New Republic*, June 27, 1994.

[21] William J. Perry, interviewed by R. Van Atta and M. Lippitz, Stanford, CA, June 6, 2001.

programs.[22] He also invited the commanders in chief of the unified and specified commands to play a significant role in DoD's resource allocation processes.[23] In 1985, Weinberger formally removed from the USD(R&E) primary responsibility for overall production policy and some key production decisions. In 1986, the Military Retirement Reform Act and the Goldwater-Nichols Act together created the USD(Acquisition) and re-established as a separate office the DDR&E subordinate to it, with much of the authorities of the former USD(R&E) position going to the USD(Acquisition). USD(Acquisition) subsequently became USD(Acquisition and Technology) and then USD(Acquisition, Technology and Logistics), as it is known today.

Since 1986, DoD's S&T program has functioned largely as a bottom-up process, with the DDR&E, under the USD(AT&L), serving largely in the role of coordinator, consolidator, monitor, and promoter of the S&T plans and programs of the Services and Defense Agencies. (With its direct access to the Services, Congress often revises elements of a Service S&T program-with or without the agreement of the Service, and often without consulting OSD. Once the money is approved, the Services execute their own programs. DARPA now formally reports to DDR&E, three levels removed from the Secretary in the DoD hierarchy.[24])

In 1991, Currie's and Perry's "technical thrusts" came to fruition in Operation Desert Storm. The capabilities demonstrated in Desert Storm—stealth; standoff precision strike; and advanced intelligence, surveillance, and reconnaissance (ISR)—represented more than just improvements in US conventional warfare capabilities. While superior training, leadership, and individual equipment accounted for a large part of the allied victory, these factors alone cannot account for achieving a 1000:1 advantage in combat losses.[25] The combined impact of better battlefield information, the ability to suppress defenses, and the ability to strike precisely at high-value targets demonstrated a new way of achieving and maintaining military control. In total, the new US capabilities effectively allowed the US to change the rules of conventional warfare in a manner that many consider to be the forefront of a broad "Revolution in Military Affairs" (RMA) in which the ability to exercise military control is shifting from forces with the best or the

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[22] Secretary of Defense Histories, "Caspar Weinberger," downloaded 4/7/05 from <http://www.defenselink.mil/specials/secdef_histories/bios/weinberger.htm >.

[23] Stuart Johnson, Martin Libicki, Gregory F. Treverton, eds., *New Challenges, New Tools for Defense Decisionmaking*, Rand Corporation, Report MR-1516 2003, p. 16, p. 31.

[24] Office of Technology Assessment, *The Defense Technology Base*, OTA-ISC, March 1988, p. 61.

[25] Perry, "Desert Storm and Deterrence," *Foreign Affairs*, Fall, 1991.

most individual weapons systems toward forces with better information and greater ability to quickly plan, coordinate, and accurately attack.[26]

With the collapse of its nemesis, the Soviet Union, the US was relieved of the intense pressure of the Cold War. Further, Desert Storm demonstrated that US military capabilities were more advanced than those of any other nation. The subsequent period of relative military superiority created an opportunity for DoD to address fundamental, long-standing issues in its S&T strategy and management. For several years, DoD saw decreasing return on its S&T investment, as commercial developers worldwide achieved shorter and shorter product turnaround, outstripping DoD's ability to absorb technological advances. By 1994, overall industrial R&D expenditures greatly exceeded those of the Department of Defense.[27] Also by 1994, the US was performing only about one-third of worldwide R&D, down from 70 percent in the 1950s.[28] By the late 1980s, the need to take advantage of rapidly evolving commercial technologies was increasingly being recognized by the defense contractors whose primary business was to develop and produce military capabilities contracted by the U.S. Government.

With these trends in mind, when Perry returned to the Pentagon as DEPSECDEF in 1993 and SECDEF in 1994, he made reform of the DoD acquisition systems a priority, so as to leverage burgeoning commercial technology capabilities, particularly in information technologies, as part of DoD's Dual Use Strategy.[29] A second priority concern of Perry's was the need to reduce overcapacity of the defense industry with the large-scale reductions in defense procurement following the end of the Cold War. To this end, Perry accelerated the broad consolidation of the US defense industry that had begun in the late 1980s.[30] Between 1990 and 1997, nearly $100 billion in mergers and acquisitions took place, with many of the biggest occurring after Perry's push.[31]

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[26] Richard Van Atta, Michael Lippitz, Jasper Lupo, Rob Mahoney, Jack Nunn, *Transformation and Transition: DARPA's Role in Fostering an Emerging Revolution in Military Affairs*.

[27] *Dual Use Technology: A Defense Strategy for Affordable, Leading-Edge Technology*, Washington, DC: Office of the Under Secretary of Defense for Acquisition and Technology, 1995.

[28] Graham R. Mitchell, *The Global Context for US Technology Policy*, Washington, DC: Department of Commerce, Office of Technology Policy, 1997.

[29] *Dual Use Technology: A Defense Strategy for Affordable, Leading-Edge Technology.*

[30] Kenneth Flamm, "Redesigning the Defense Industrial Base," in Ann R. Markusen and Sean S. Costigan, editors, A*rming the Future: A Defense Industry for the 21st Century*, New York: Council on Foreign Relations Press, 1999, p 224-246.

[31] John J. Dowdy, "Winners and Losers in the Arms Industry Downturn," *Foreign Policy*, Summer 1997, pp. 88-101.

The Clinton Administration presented these measures as elements of a broader National Security Science and Technology Strategy, stating:[32]

> To increase the performance and reduce the costs of new defense technologies, the Administration has launched initiatives that reflect new ways of doing business. *Acquisition reform* removes barriers that separate the defense industry from the commercial industry… Our *dual-use technology policy* recognizes that our nation can no longer afford to maintain two distinct industrial bases and allows our armed forces to exploit the rapid rate of innovation of commercial industry to meet defense needs. The Technology Reinvestment Project supports that policy by leveraging commercial technology advances to create military advantage. In addition, to continue the development of advanced, operationally-relevant technologies without making expensive commitments to product procurement, the Administration has developed the *Advanced Concept Technology Demonstration* initiative.

To effect this strategy, Perry implemented a series of acquisition reform measures—The Federal Acquisition Streamlining Act of 1994 (FASA), the Federal Acquisition Reform Act of 1996 (FARA), the Single Process Initiative, Cost as an Independent Variable (CAIV), the Open Systems Initiative, the Software Management Initiative, Other Transactions Authority, and the Information Technology Management Reform Act of 1996 (Clinger/Cohen Act), as well as other programs—to sweep away regulations and practices that inhibited the use of commercial technology and practices in defense systems. In addition, several programs were instituted to encourage "commercial technology insertion" and to foster technology development partnerships between defense contractors and commercial suppliers. The most ambitious of these was the Technology Reinvestment Program (TRP), initially slated as a nearly $1 billion program over three years, with $600 million in the first year program. Other "dual use" programs included the Commercial Operations and Support Savings Initiative, the National Flat Panel Display Initiative, and the Commercial Technology Insertion Program.[33]

Also at this time, with the strong support of Under Secretary of Defense for Acquisition and Technology Paul Kaminski a new organizational entity, the Deputy Under Secretary for Advanced Technology, was established, headed up by Larry Lynn, to focus on the transition of innovative technologies into military application through the new mechanism of Advanced Concept Technology Demonstrations (ACTDs)—with the initial focus on getting Unmanned Aerial Vehicles (UAVs) into military operators hands

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[32] "Executive Summary," *The National Security Science and Technology Strategy*, Washington, DC: the Office of Science and Technology Policy, Executive Office of the President, September 19, 1995.

[33] Many elements of this program were sharply cut back by the Republican-controlled 104th Congress, specifically the TRP, but the focus on acquisition reform and dual use remained.

for application experimentation.[34] This new organization was created as a means of getting new military innovations into the field—"crossing the chasm" from R&D to use by allowing experimentation with "fieldable prototypes."

In the midst of the organizational refocusing on dual use and acquisition reform, DoD maintained an interest in supporting Defense S&T with priorities in information technology, sensors, and modeling and simulation.[35] A particular focus of Under Secretary Kaminski was to achieve "dominant action cycle time" by combining "precision strike weapons, improved mission planning systems and superior C4ISR…[to] …allow the US to deploy small, more lethal, and dispersed units to accomplish missions performed today by much larger forces."[36] However, in this period of decreasing defense budgets, in which the weapons' modernization accounts had declined 45 percent since the end of the Cold War, it was a challenge to maintain S&T resources at desired levels.[37]

Beginning in 1990, a series of Defense Science Board studies began to contemplate the post-Cold War security environment, starting with an in-depth, five-volume examination entitled *Research and Development Strategy for the 1990s*.[38] This study put forward the following principal recommendations:

- Establish a "CEO" for technology, with the responsibility to develop and implement an R&D strategy that responds to a future characterized by lower budgets, fewer opportunities for new starts, and more uncertainty about future adversaries.
- Recognize the significance of stealth/counterstealth technology as one of the major breakthroughs of this quarter century.
- Ease of deployability should be a major criterion for all tactical systems
- Re-orient strategic programs and continue force modernization to meet the challenges of the restructured world: numerically reduced US/Soviet forces and increasing Third World nuclear threat.
- Reprioritize intelligence needs and resources… (to) strengthen the ability to provide worldwide intelligence.

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[34] Larry Lynn, "Advanced Concept Technology Demonstrations: Today's Technology for the Warfighter," *Army RD&A*, September-October 1995, 4.

[35] *The National Security Science and Technology Strategy*, September 19, 1995.

[36] Dr. Paul G. Kaminski, "Defense System Technologies of the 21st Century," Address of the Under Secretary of Defense for Acquisition and Technology to the ADPA Winter Luncheon, Fairfax, VA, February 28, 1997.

[37] Statement by Dr. Anita K. Jones, Director of Defense Research and Engineering. to the Subcommittee on Military Research and Development of the House National Security Committee, February 27, 1997.

[38] Defense Science Board, *Research and Development Strategy for the 1990s*, Washington, DC: Office of the Under Secretary of Defense (Acquisition and Technology), 1990.

- Initiate policies to attract and retain the most capable people available to provide the underpinnings for the above recommendations.

The next section of this paper builds on the idea of the first recommendation—the creation of a technology "CEO" for DoD—in the context of how major US industries coped with the changing technology and competitive environment of 1980s and 1990s.

## III. THE RISE OF THE CHIEF TECHNOLOGY OFFICER

A notable dynamic of the 20th century was the concentrated efforts by governments to harness S&T for political and economic advantage and the drive by competing private firms to capitalize on these ideas. For national governments, the harnessing of new technologies derived from scientific advances was seen as having fundamental implications for economic competitiveness and security. For firms in high-tech industries, it was seen as fundamental to a firm's ability to compete and survive.

Around 1900, the leading firms in science-based industries, including GE, AT&T, DuPont, Corning, and Kodak created corporate R&D programs, generally for the same reasons:

*Competition*—These companies perceived threats to their core technical advantages. Urged on by scientifically oriented managers, the firms set up laboratories as a form of life insurance.

*Federal antitrust action*—Executives believed they could overcome federal suspicion of large-scale industry by rationalizing their businesses and striving to compete based on innovation.

*Internalization*—Investments in R&D were part of a general movement toward internalizing functions such as manufacturing and marketing within corporate management hierarchies, rather than relying on external suppliers in the market. This was also the time during which corporations began organizing themselves into product divisions, raising the issue of whether to centralize R&D or leave it attached to product groups.

*Diversification*—The outbreak of World War I enhanced US corporate R&D in several ways. Cut off from German dye and pharmaceutical industries (and aided by the confiscation of German patents as "alien property"), US chemical and pharmaceutical companies established R&D labs. Scientific elites seized on the opportunity to promote the development of domestic R&D establishments, buoyed in part by the successful application of science to wartime problems such as chemical warfare and submarine detection. (The Naval Research Laboratory can trace its origins to World War I.)

Between 1919 and 1936, US manufacturing firms established 1,150 industrial research laboratories. The number of industrial research professionals (scientists and research engineers) employed by these firms grew from 2,775 in 1921 to 27,777 by 1940. By the end of the interwar period, a formula for industrial R&D seemed to have emerged:

Conduct world-class fundamental research and you will find important new, proprietary products with potential for highly profitable commercialization.[39]

World War II fostered the “Age of Big Science.” Spurred by the needs of World War II, American commercial industry played a vital role in developing and implementing fundamentally new capabilities and new areas of technology. Firms such as General Motors, Ford and Chrysler; General Electric and Westinghouse; AT&T; and IBM were mobilized to support the war effort both with their industrial production and their technological capabilities. Such firms joined with government labs and universities to bring fundamental new capabilities into being for meeting defense needs. This interlinking of private companies, academia, and government to foster and deliver new capabilities for America’s defense caused a new and profound shift in the concerted pursuit of science and technology to achieve advantage.[40]

Vannevar Bush’s *Science: The Endless Frontier*[41] helped them along by promoting the so-called “linear model” of development: the idea that investment in the “best science” would yield a cornucopia of new technologies and products. The linear model was reinforced by the creation of high-profile corporate laboratories at such firms as IBM and Ford and the large-scale expansion of basic research at existing corporate laboratories, such as those at DuPont and AT&T. It was also reinforced in the 1950s by widening appreciation of the commercial implications of Bell Labs’ invention of the transistor. Frederick Terman, one of Bush’s MIT students, built on the idea of science-technology interaction by fostering academic-industrial partnerships with companies near Stanford University, which eventually begot Silicon Valley.

Over the last two decades, much has changed to cause those in government and industry to reconsider the approaches to S&T that were so patently successful before. In the 1980s, worldwide competitive pressures undermined once dominant market positions, and a crisis in confidence grew in US industry—beginning with heavy industry and

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39 R. Van Atta, R. Bovey, J. Harwood, W. Hong, A. Hull, B. Kindberg, and M. Lippitz, *Science and Technology in Development Environments*, Institute for Defense Analyses, Alexandria, VA, IDA Paper P-3784, May 2003.

40 John Foster emphasizes the instrumental role of university professors and their graduate students in providing breakthrough capabilities in World War II. “Professors and their grad students” led both the development of radar (through the MIT Radiation Laboratory), which played such a key role in the Allied victory in Europe, and the atomic bomb (through the Manhattan Project) that ended the war against Japan. John Foster, interview, May 09, 2005.

41 Bush, Vannevar, *Science: The Endless Frontier, A Report to the President by Vannevar Bush, Director of the Office of Scientific Research and Development, July 1945* (United States Government Printing Office, Washington, D.C.: 1945).

moving to high tech over the decade as first Japan and then other Asian economies captured increasing market shares. Firms began to focus on near-term manufacturing and rapid product development and, in the funding pinch caused by this relentless new competition, began to cut future-oriented R&D to address the crisis of lost market position and mounting financial losses. Competition transformed in many industrial segments from the national to the regional and even now to the global arena.

At the same time, a global diffusion of science and engineering capabilities has been promoted by the rapid expansion of higher education in many regions and the global access to world-leading US university science programs. Many countries in Europe and Asia have placed particular emphasis on science and engineering education, while in the US, support has declined.[42] Today, European science and engineering doctorates exceed those in the US by 30 percent; Asian-granted doctorates have been about half those of the US. While foreign students enroll disproportionately in US science and engineering programs—25 percent of masters and 47 percent of doctorate degrees in science and engineering granted by US universities are to foreign students—Asian countries have been rapidly expanding their indigenous doctoral programs in science and engineering.[43] While the US is the leading individual country, both Europe and Asia are highly involved in scientific education, and students worldwide are accessing science education opportunities.

A major product of these pressures in the US was the shutting down or significant scaling back of many corporate research laboratories in the 1980s and 1990s, as firms questioned the ability of their internal scientific establishments to produce useful results, especially results that directly and particularly benefited their organizations.[44] Although considerable attention was given to "technology transfer," the process was seen as highly inefficient, giving rise to considerable doubt about the value of investing in scientific endeavors, especially those that entailed large-scale facilities and would take some time to bear fruit. The "Age of Big Science" was ending.

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[42] Richard B. Freeman, "Does Globalization of the Scientific / Engineering Workforce Threaten US Economic Leadership?" Cambridge, Mass: Harvard University, Paper prepared for the Innovation Policy and the Economy Conference, Washington, DC: April 19, 2005. Moreover, in the last 20 years the military services have reduced graduate work at universities in science and engineering—particularly systems engineering (John Foster, interview May 9, 2005).

[43] *NSF Science and Engineering Indicators,* 2004; see also Diana Hicks, "Trends in Asian R&D," Washington, DC: ASME 3rd Annual Engineering R&D Symposium, April 5, 2005.

[44] During the same period, several Asian high-tech firms opened large-scale research facilities, such as Samsung's Advanced Institute of Technology, founded in 1987.

Rather than invest primarily in internal labs, some industry players turned to collaborative efforts, including consortia (such as SEMATECH and MCC) and partnering in research through corporate joint ventures and similar arrangements. The growth in the diversity of research organizations and their globalization was one of the major developments of the 1980s and 1990s, with firms looking externally for new ideas and new partners to help develop and bring new concepts to fruition. (With the end of the Cold War, one could even contract R&D in Russia at a fraction of the cost of research in the United States.) Industrial research moved away from hierarchical, linear models to flexible technology partnering and/or outsourcing arrangements.

In a 1998 survey of 308 CEOs, "globalization" was judged to be the most important trend affecting companies.[45] Intensified international competition was driving companies to seek out technical talent worldwide. Distributing R&D functions helped companies access this talent. In the face of increasingly complex technologies, where leading-edge research often necessitated acquiring expensive fixed capital, companies were also tending to focus on selected core competencies while seeking partnerships and alliances to obtain other needed capabilities.

The advent of the Internet fostered this trend by facilitating distributed work. Various information technology tools have been and are being developed to help geographically distributed researchers collaborate in "virtual laboratories." R&D managers are increasingly supervising both internal and external research projects and are being called upon to maintain awareness of worldwide technical developments—so-called "technical intelligence." Entire software categories have arisen to encourage and support distributed collaborative efforts.

In short, corporate research and development has transitioned from being focused on doing good science, publishing papers, and perhaps discovering something translatable into a new product or process, into an integral component of an operating company. No longer are corporate laboratories predominantly populated by people who have never set foot within a manufacturing plant. In state-of-the-art firms, scientists and engineers are now part of cross-functional teams working with sales, marketing,

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[45] "The Nations CEOs look to the Future," survey conducted by Louis Harris & Associated for the Baldrige National Quality Award Foundation, July 1998, as cited in Charles F. Larson, "Industrial R&D in 2008," *Research Technology Management*, November-December 1998.

operations, and finance people to develop new and improved products and/or processes in addition to raising the core technical competencies of their companies.[46]

The concept of the "Chief Technology Officer" emerged from this environment. In the old model, technology-oriented companies might have a chief scientist or a lab director whose main job was to manage internal technology development. As the "linear model" of technology development began to be abandoned, and as investment in R&D broadened and expanded within the private sector, technology companies recognized that they needed a person to think strategically about trends in the wider technology world.[47] Key questions included, "What are emerging technologies, and where are they headed? In what areas are we ahead? In what ways might we be vulnerable? How might we link to companies doing leading-edge R&D of significance to our business?" The CTO might also serve as the executive director of the company's internal technologists, but this was no longer that person's primary focus. Rather, in most cases that person would need to focus more on technology realization/commercialization, as well as managing the increasingly subtle and complex world of strategic technology licensing, offshore partnerships, and R&D tax policy.[48]

Based on previous research,[49] the following items are among the typical roles of the modern CTO:

- Advocates science and technology to the CEO, Board of Directors, and Executive Council
- Advocates for S&T in general as an activity deserving corporate support
- Maintains top management sponsorship for specific projects that have special potential
- Informs corporate strategy with technology issues.
- Role of the Lab in new directions and support of divisions

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[46] D.P. Parker and Associates, "The Changing Role of the Chief Technical Officer," downloaded 1/20/05 from http://www.dpparker.com/article_cto_role.html. Also see Roger Smith, "The CTO in Transition," CTOnet.org, 2004.

[47] Roger D. Smith, "The Chief Technology Officer: Strategic Responsibilities and Relationships," *Research Technology Management*, July-August 2003.

[48] Peter Cannon, "What Does it Mean to Be a CTO?," *Research and Technology Management,* forthcoming.

[49] R. Van Atta, R. Bovey, J. Harwood, W. Hong, A. Hull, B. Kindberg, and M. Lippitz, *Science and Technology in Development Environments*, Institute for Defense Analyses, Alexandria, VA, IDA Paper P-3784, May 2003. As noted in this study the role of the CTO varies considerably from firm to firm, and even within individual firms the position has changed over time, especially as the firm changes its strategy in terms of technology.

- Envisions and leads the design of an R&D portfolio that supports corporate strategy
- Searches for trends in science and the market that offer opportunities or dangers
- Identifies critical technologies supporting corporate strategy, including valuation and protection of key patents and trade secrets
- Identifies needs and opportunities within operating units to which R&D can contribute (e.g., enhancing customer value, cost reduction, etc.)
- Supports collaborative mechanisms to leverage technology capabilities across organizational divisions
- Balances investments in R&D aimed at sustaining on-going operations with those aimed at radical innovation.
- Manages R&D activities (usually through subordinates or committees)
- Project selection, continuation, and termination
- Seeks out and sponsors relevant external research, technology licensing, partnerships, and consortia (including analysis of potential mergers or acquisitions and integration of acquired R&D capabilities)
- Transitioning projects from research to development to implementation (with personal oversight of special projects aimed at innovations that will dramatically affect the corporation)
- Technical personnel selection, training, oversight, and promotion, with special attention to selection and mentoring of project champions
- Laboratory and technical infrastructure administration.

## IV. FRAMING TODAY'S DOD S&T MANAGEMENT AND STRATEGY PROBLEM

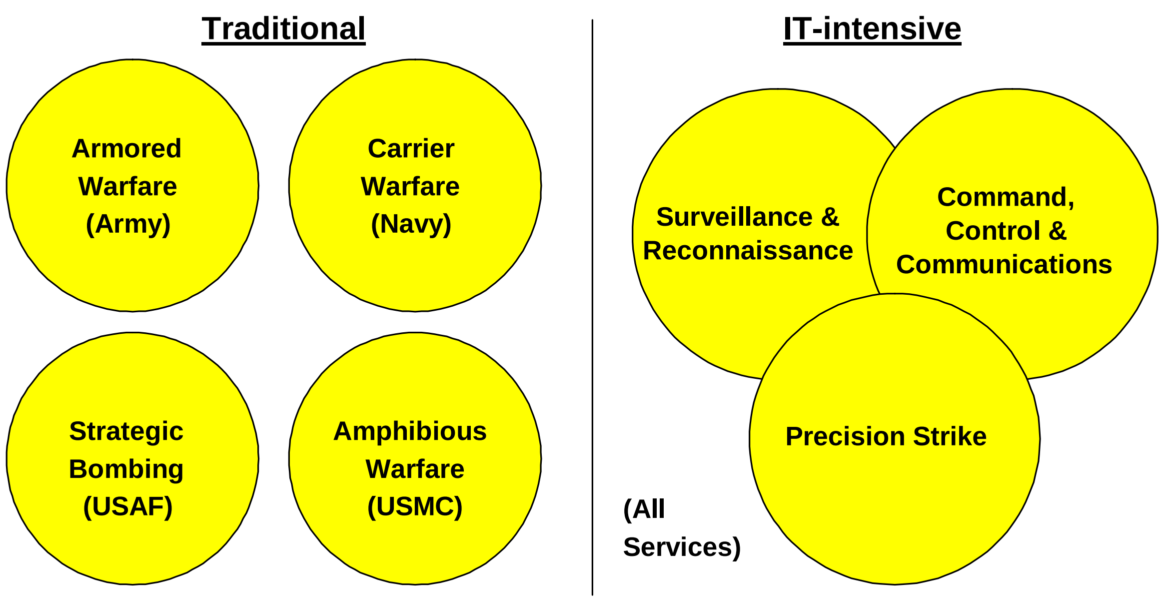
We conclude our paper with some consideration of DoD's approach to addressing the broad strategic S&T management issues it faces today. The technological superiority of US military forces was the underpinning of the security strategy of United States for the last half of the Twentieth-Century and continues in that role today. This technological superiority was built on the world's strongest and most vibrant national S&T and industrial bases. These strengths have been supported by the world's largest single economy, as well as the financial power and the national will to invest in science and exploit the technological results for both defense and commerce. While other nations have had strengths in individual technical areas, in the post-World War II era none has been able to match the US S&T investment for national security.

The ability of the United States military to sustain a position of technological superiority is being fundamentally challenged in many ways. The nature of the threat to the US is changing, with an immediate focus on regional conflicts and "asymmetric" adversaries with potential access to weapons of mass destruction, and a longer-term focus on the potential rise of a new peer competitor. The nature of technology is changing, with the rapid worldwide investment in and adoption of various "information technologies," as well as poorly understood but potentially momentous emerging technologies such as biotechnology and nanotechnology. Finally, there is globalization, in particular the increasing global diffusion of science and technology, the dispersion of industry facilities and industry ownership, and the interconnection of all the world's economies. This increases the importance of looking at new intelligence capabilities with an eye toward long term investments.

DoD S&T planning and experimentation mechanisms are too slow and insufficiently aggressive to adequately address today's threats. For example, DoD is now addressing problems of asymmetric conflicts in which there is a need to respond rapidly to dispersed adversaries, especially in urban areas where they seek to evade a major US strength—the ability to deliver stand off precision strikes. The speed and agility of DoD's response to these threats has been criticized as not providing needed "quick fixes" quickly enough. Further, while the emphasis on "quick fixes" that can be fielded in the short term is understandable given the current situation in Iraq, it is clear that DoD S&T needs an approach that encompasses all urban conflict based on an integrating concept—as has been articulated in the Joint Urban Operations Master Plan. The Joint Forces Command's Urban Resolve simulation-based experiment provides a basis for defining an overall system of capabilities in an integrated manner, rather than developing numerous individual weapons and other systems and applying these in a *post hoc* manner. OSD should take the lead in investing the time and resources into adopting such approaches to provide integrative perspectives for technology development processes.

DoD has yet to face squarely the global diffusion of technical knowledge and capabilities. In the defense area in particular, many firms, dependent on exports for their survival in an era of consolidation, are offering a wide array of sophisticated defense and dual-use products worldwide. These firms—especially outside the US—focus largely on customers worldwide and only secondarily on traditional domestic ones. Rationalization and downsizing are leading to a smaller number of ever more powerful suppliers. Technology transfer is increasingly becoming a matter of exchanging knowledge rather than the physical transfer of equipment. In many cases, technical know-how from foreign scientists and engineers can be hired and weapons test facilities and equipment can be rented.

More deeply, competitiveness in the defense industry is increasingly being defined in terms of competitiveness in accessing and integrating information technology (IT)—largely from the commercial sector—into "systems of systems." Certain types of vertical integration are required if a company is to provide complete solutions. Consider the conceptualization of past and present defense markets represented in the graphic below.[50] In each of the modern market domains—surveillance and reconnaissance, C4I, and precision strike—competence in several different information technologies is central to success. In the commercial world, firms have determined that collaboration and cross-firm partnerships are increasingly needed to provide the multiple competencies to develop the integrated products that bridge once-distinct market areas. This convergence of markets is driven by the integration of multiple technologies into complex, multifunctional products (Systems in Package).[51] This dynamic underscores the importance of developing effective cross collaboration between defense and commercial industry, as the primary drivers of these trends are commercial applications.

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[50] Loren B. Thompson, "The Post-Deconstruction Defense Industry: Now What?" Washington, DC: Lexington Institute, September 9, 1998.

[51] *iNEMI Technology Roadmaps, Executive Summary*, Herndon, VA: International Electronics Manufacturing Initiative, December 2004.

# V. TOWARD A FOCUSED DEFENSE INVESTMENT STRATEGY TO MEET THE CHALLENGES OF THE GLOBAL TECHNOLOGY ENVIRONMENT

Several processes have contributed significantly to the successes of OSD S&T management in producing the significant technological and operational military superiority that the US currently enjoys. These processes may be thought of in two general categories: *vision* and *leadership*. Vision involves conceiving, developing, and demonstrating new capabilities. Leadership involves moving demonstrated capabilities into acquisition and deployment. Reflecting on the new environment of global technology, DoD needs to focus on five fundamental elements of an investment strategy for the future.

## 1. Investing in basic technologies that can lead to fundamental technical advantages

Both the DDR&E and DARPA roles in performing research into emerging technologies—before their national security significance becomes clear—has supported US dominance of entirely new industries. DARPA has often served as DoD's corporate research activity, moving rapidly into new thrust areas and exploring opportunities that could "change the business."

There are concerns today that DoD is not making the sustained, long-term investments in science and technology needed for fostering the technology base for future capabilities. It takes time and consistent support to build the knowledge base from which entirely new products emerge. Many countries—Japan, Korea, Taiwan, China, and India—are targeting such support on applications of advanced technologies. This places great stress on sustaining US S&T prowess as a basis for maintaining technological leadership.[52] *Reformulating approaches for S&T investment in the current world environment may be one of the most significant issues facing DoD and the country in the coming years.*

## 2. Building communities of change-state advocates.

Getting the best people is crucial. DDR&E and DARPA often recruited top people inside and outside of government to pursue innovative ideas. These people acted as catalysts for cross-fertilization among academic researchers, military operational experts, and private industry. DDR&E's focus of internal Service S&T was used to create a "critical mass" of research activity around such efforts.

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[52] *Assessing the Capacity of the U.S. Engineering Research Enterprise*, National Academy of Engineering, Preliminary Report for Public Review, 2005.

Today, DoD appears to be increasingly isolated from the sources of innovation—which are more and more in commercial sectors and international in nature.[53] Unacceptable trends in R&D investment and technical education raise concerns on our potential to create and develop "game changing" technologies.

*With the internationalization of science and technology in academia and in commercial industry, DoD will be increasingly challenged to build and maintain access to the leading sources of technological know-how.*

### 3. Defining strategic challenges in detail across multiple scenarios

By undertaking study efforts in the 1960s and 1970s that defined and articulated *in detail* fundamental, strategic challenges facing the US, OSD helped set and promulgate research priorities across the defense S&T community. The future security environment has much more potential variability than when the US faced a single dominant adversary in the Soviet Union. DoD has developed some new capabilities for assessing future security challenges and determining how technological capabilities might address these challenges. For example, at a broad strategic level, OSD is leading an effort to develop a new set of wide-ranging defense planning scenarios. An operational level example is the Urban Resolve, mentioned earlier. *Establishing an integrated approach employing such assessment capabilities to guide and integrate DoD's technology development priorities would be a useful means to come to grips with the complexities of the future security environment.*

### 4. Developing disruptive systems concepts and testing promising disruptive concepts through large-scale, integrated demonstrations

Based on well-defined strategic challenges, DDR&E and DARPA conceived novel integrated concepts linking technical capabilities with defense missions, breaking Service-specific paradigms. These were not simply the articulation of technology thrusts but rather well defined, outcome-oriented programs of technology development and systems experimentation. Demonstrations of large-scale, high-risk concepts convinced DoD leadership, Congress, and the Services of the potential value of new approaches. In the past, OSD's leadership has been crucial to turning S&T into real systems. Transition from promising technical concepts to fielded military capabilities has been difficult and vexing, especially if the capabilities were "disruptive" of current ways of doing business.

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[53] *Report of the Defense Science Board Task Force on the Technological Capabilities of Non-DoD Providers*, Washington, DC: Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics, June 2000.

Because acquisition and deployment of new capabilities generally challenges existing programs, processes, and organizations, requiring new operational concepts and related tactics, training, and procedures, it is difficult to find Service customers eager for them. Also, because new capabilities are not technically mature or operationally robust, the Services will generally be reluctant to take on the significant and potentially costly risk reduction efforts required to move them into acquisition.

Prototype and demonstration programs provide mechanisms for reducing risk and promoting transition, especially if they bring the technical and operational communities together in a joint enterprise. Clearly if these are brought together early in the conceptual process and work interactively to address implementation while the system is developed and as it evolves, there is likely to be a smoother and perhaps earlier transition—although the challenges of bringing significantly new capabilities to the field should not be underestimated. The transition issue is magnified when joint capabilities are involved. DoD has attempted or considered various approaches for addressing the transition from R&D into acquisition, including Joint Program Offices and even at one time a Defense Prototyping Agency, but most of these have been sporadic, idiosyncratic, or short-lived experiments or pilot programs. Advanced Concept Technology Demonstrations (ACTDs) have been employed as one approach for fostering application experimentation. While useful, these are focused on the near term, with little technical risk employing a consensual process. *Transitioning potentially "transformational" military capabilities from R&D into acquisition remains a major challenge. OSD needs to continue to provide both leadership and creativity in fostering "bridging" mechanisms for moving innovative concepts and technologies into application and acquisition.*

### 5. Providing a clear, top-level imprimatur for risk reduction and acquisition of specific capabilities

Top DoD leadership commitment to implementation has always been instrumental in addressing acquisition issues involved in maturing technology and bringing systems to fruition. This will be even more the case in the future as "born joint" warfighting capabilities are required. The security environment of the future is fraught with uncertainty and requires *flexibility and agility* in developing new concepts and the technological capabilities for implementing these concepts, experimenting with them, and bringing them to fruition rapidly. *A strong leadership role in OSD—a position akin to the CTO of a high-tech firm—for defining, guiding, and supporting the processes to further the development and transition of such new technological capabilities is required.*

## VI. CONCLUSIONS

While a full prescription for appropriate DoD strategic S&T management in the face of these challenges is beyond the scope of this paper, the DoD and industrial management histories provide some insight into the prerequisites for success. The observations above imply that OSD S&T management requires:

- A "CTO-like" officer in DoD, with a direct and close working relationship with the SECDEF and DEPSECDEF, who provides the authority, imprimatur, and resources (including personnel) for [1] assessing the emerging security and technology environment; [2] providing a top-down strategic perspective and explicit guidance on the needed technology direction and priorities to be responsive to this environments and its attendant uncertainties; and [3] owning the management authorities when needed, to:
    - redirect/cancel specific S&T investments, whether internal projects or external partnerships, toward DoD-wide priorities
    - run independent S&T programs in areas not being pursued by others
    - promote the realization of new technologies through experimentation, demonstration and advanced prototyping programs.
- A trusted staff with detailed technical competency in all technologies of known significance ("core technologies") and resources to explore emerging technologies whose national security significance is not yet clear. Personnel resources need to be directly available to systematically interact with commercial industry to scout, assess, and gain access to emerging technologies, and to determine whether and how DoD should develop defense-specific approaches for meeting advanced or highly specialized needs. Given the vagaries of commercial industry relative to meeting defense needs in technologies vital for future superiority of weapons, a capable staff focused on developing appropriate options, strategies, and investments is required.[54]
- Direct contact with Joint Staff, COCOMs, and Components to understand needs. OSD needs to support and engage the efforts of the Joint Staff and Joint Forces Command to define new concepts that anticipate the capabilities needed for future missions and forces. The processes of experimentation currently under way need to be coupled to the S&T planning process in an iterative, adaptive manner. OSD needs to take the lead in forging the mechanisms that moves novel technological capabilities into the hands of the warfighter so they can be assessed, their potential evaluated, and subsequently moved into initial applications without having to traverse the rigid hurdles of the acquisition system.

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[54] For a recent assessment demonstrating DoD's needs to develop forward thinking perspectives and strategies for technologies vital for defense, see *High Performance Microchip Supply*, Defense Science Board Task Force Report, Washington DC: Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics, February 2005.

- Support from Congress, to:
    - Fund a robust OSD S&T effort for conducting technology search and assessment and to attract top people to undertake intensive oversight and leadership of specific programs
    - Take needed measures, including if necessary changing public law, to give OSD greater flexibility in setting up outcome-oriented programs that cross-pollinate DoD technology capabilities across Service boundaries
    - Hold the USD(AT&L) and the SECDEF accountable for implementing the DoD technology strategy.

While it may be difficult to achieve change when the US military is felt to be quite capable and successful, and especially without the type of clear, strategic imperative that drove the current, IT-based "revolution in military affairs," the technology environment that DoD now faces and will face in the foreseeable future requires a new approach to defense technology management. Guided by an understanding of evolving defense needs and emerging technologies, OSD needs to formulate and implement an agenda—fusing high-level policy, technology, and operational concerns—for the development of the capabilities that will provide the US with strategic competitive advantages in the future.[55]

[55] Richard Van Atta and Michael Lippitz, *Transformation as Transition: DARPA's Role in Fostering an Emerging Revolution in Military Affairs*, IDA Paper P-3698 (Alexandria, Va.: Institute for Defense Analyses, March 2003).

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**13. SUPPLEMENTARY NOTES**

**14. ABSTRACT**

This study, supported as a Independent Research Project by the Institute for Defense Analyses, provides a perspective on how changes in the economic and technological arena—often referred to under the rubric "globalization"—bear upon the Department of Defense's approach to conducting and managing its research and development. This study discusses: lessons learned from past DoD S&T management efforts and initiatives, especially those within the Office of the Secretary of Defense (OSD), and how industry has coped with globalized competitive threats and the explosion of new technologies, with a focus on the roles and functions of Chief Technology Officers (CTOs) in various commercial contexts.

**15. SUBJECT TERMS**

Defense technology management; Director, Defense Research and Engineering; Chief Technology Officer; globalization

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