

INSTITUTE FOR NATIONAL STRATEGIC STUDIES

DEVELOPING BATTLEFIELD TECHNOLOGIES IN THE 1990S

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NATIONAL DEFENSE UNIVERSITY

McNair Paper 21

***A popular Government,
without popular information or the means of
acquiring it,
is but a Prologue to a Farce or a Tragedy; or
perhaps both.
Knowledge will forever govern ignorance;
And a people who mean to be their own
Governors,
must arm themselves with the power which
knowledge gives.***

JAMES MADISON to W. T. BARRY

August 4, 1822

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NATIONAL DEFENSE UNIVERSITY
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PREFACE

Two momentous events have reshaped the way the Department of Defense (DOD) conducts its business. The first, the dissolution of the Soviet Union, perhaps the most significant event of the past decade, changed the mix of technologies DOD needs to execute its mission. Future conflicts are now much more likely to be conventional than nuclear, regional than global, and tactical than strategic. Hence, new technologies must be developed and blended with existing technologies to cope with a greater variety of battlefield conditions.

A second momentous event, Desert Storm, realerted the world to the importance of technology. Of great importance to the coalition forces, for example, was that technology saved lives. Although the outcome of Desert Storm vindicated past military predilection and investment in technology within the U.S. forces, it also rekindled concern for preserving a technological edge and accelerated adoption of a new acquisition approach to that end.

Just as demand for new battlefield technologies has again strengthened, DOD faces chronic budget cutbacks. As Admiral David E. Jeremiah, Vice Chairman of the Joint Chiefs of Staff observed, "Our position is similar to that of the Royal Navy roughly 100 years ago, when the British introduced a new class of large, fast, heavily armed warships. Overnight the new Dreadnought class, essentially the first modern battleship, made every other type of surface

combatant obsolete."

The irony for the British was that this made the rest of the Royal Navy, the strongest navy in the world, obsolete as well. The British had to start over like everybody else, and this meant that competition could take a shortcut. Nations like Germany, which had never dreamed of challenging the Royal Navy before, could capitalize upon their industrial strength to become formidable sea powers simply by building fleets of new dreadnoughts as fast or faster than the Brits.¹

To help ensure that history is not repeated, new policies had to be fashioned. Hence, current defense technology policy has two major thrusts. The first is aimed at helping the nation maintain its technological competitiveness. The plan is to transfer technology from the federal laboratories to private firms. The second thrust is designed to grow promising technologies more quickly and more affordably through a new acquisition strategy.

The contributors to this compendium of papers look at both defense technology thrusts: the technology transfer issue and the new acquisition approach. All but the last chapter are abridged versions of research papers required for graduation from the Industrial College of the Armed Forces, National Defense University.

Colonel Thomas Humpherys, Ph.D, former Detachment Commander for the Air Force Space and Missile Systems Center, Deputy Director of Flight Test Engineering for the 4950th Test Wing, and international research liaison officer in London, believes a strong defense technology base

1. Jeremiah, David E., Admiral, USN, Vice Chairman of the Joint Chiefs of Staff, in a speech delivered to the Industrial Base Symposium, Industrial College of the Armed Forces, National Defense University, April 1993, pp. 3-7.

requires a strong national technology base. His chapter, "Federal Initiatives to Transfer Technology to Private Industry," is the culmination of many interviews with private and government managers, particularly those active with CRADA, the Cooperative Research and Development Agreements program. He argues that successful technology transfer from government laboratories to private industry will depend on achieving constructive matches between technology producers and intended users.

Lieutenant Colonel Robert Gamache, Ph.D., member of the Air Force senior acquisition corps and former Director of Satellite Integration and Test MILSATCOM Program Office, Air Force Materiel Command, agrees that the new S&T strategy is a step in the right direction, but argues that it must be accompanied by comprehensive reforms of the defense acquisition process. New technologies will not see the light of day unless they can be fielded affordably. His chapter, "The Defense Acquisition Challenge: Fielding Affordable Weapons," offers program managers specific policy recommendations to help control the escalation of weapon system costs.

Colonel Robert Chedister, test pilot and former squadron commander and deputy commander for operations at an Air Force flight test center, offers some important insights as to how testing can help make DOD's new Science and Technology Strategy a success. In his chapter, "Testing: The Bridge to Success for the New Science and Technology Strategy," he recommends: early user involvement in the test and evaluation (T&E) process; tester input as to when a technology is ready; ATD teams consisting of scientists, testers, and users; and tester management of the ATD program.

Lieutenant Colonel Jerry Wiedewitsch, former armor

battalion commander and Department of the Army staff officer, articulates users' concern about the proposed Science and Technology policy. Mindful that past mistakes must not be forgotten, he concentrates on what is most important to users. His chapter, "Technology Timeliness from a Soldier's Perspective," draws attention to an oft-forgotten truism: technological superiority never equates to warfighting superiority unless technically advanced weapon systems are fielded when soldiers need them.

Edwin R. Carlisle, Ph.D., Professor of Economics and Technology at the Industrial College of the Armed Forces, National Defense University, argues that defense planners should be aware of the trade-offs inherent in a new acquisition strategy aimed at preserving technological supremacy. Forces can either optimize resources with regard to mission effectiveness, or with regard to technology maximization, but not both simultaneously. A rule of thumb, a decision rule, is derived for program managers and defense planners, should technology rather than mission become the target variable.

All members of the Research Seminar responsible for this monograph would like to thank Lieutenant General P. G. Cerjan, President of the National Defense University; Rear Admiral J. F. Smith, Jr., Commandant of the Industrial College of the Armed Forces, and Dr. John H. Johns, Dean of Faculty and Academic Programs (ICAF), for providing an environment conducive to focused research. All views expressed in this manuscript are, however, those of the individual authors and not necessarily those of the National Defense University, the Department of Defense or the U.S. Government.

E. R. C.

1

Federal Initiatives to Transfer Technology to Private Industry

THOMAS W. HUMPHERYS

ABSTRACT

Successful technology transfer from U.S. government organizations to private industry depends upon achieving constructive matches between technology producers and intended users. This paper assesses government efforts to transfer technology and provides recommendations to better utilize federal resources to stimulate technological innovation and promote U.S. industrial competitiveness.

Technology has been the foundation of America's economic and military strength. As a new world begins to unfold, however, budget deficits, trade imbalances, and technology shortcomings have begun to jeopardize U.S. leadership. To stimulate technological innovation and economic growth, U.S. lawmakers have directed federal scientists to transfer technology developed within federal laboratories to private industry. How might these federal resources be better utilized to enhance U.S. industrial competitiveness?

Exploiting Federally Conducted R&D

With over 720 federal laboratories, employing more than one-sixth of U.S. scientists, and consuming nearly \$20

billion a year conducting research and development (R&D), the U.S. government's investment in R&D is unequalled.¹ Federal laboratories and research facilities, in particular Department of Defense (DOD) and Department of Energy (DOE) laboratories, offer a wealth of technical expertise which, in many cases, could be transferred to industry with potential commercial applications. Previously concerned only with government needs, most federal laboratory workers concentrated in specialized areas with little regard to spinoff technologies for commercialization. As a result of recent congressional legislation, federal agencies have initiated a number of programs to facilitate the transfer of technologies to the private sector.²

Federal Agency Initiatives

The government established several organizations to help industry gain access to federal R&D resources. These include the National Technology Transfer Center, Regional Technology Transfer Centers, Federal Laboratory Consortium Locator Network, Federal Laboratory Consortium, and the National Technology Initiative. The first three in this list provide limited training in order to initiate an effective transfer of technology, and direct interested researchers to the right federal laboratory.³ The other two warrant further discussion since they bring together scientists and engineers from academia, industry, and government to disseminate information on federal laboratory capabilities and resources.

Federal Laboratory Consortium. FLC was officially chartered by the Federal Technology Transfer Act of 1986⁴ to strengthen technology-based cooperation between the federal laboratories and U.S. businesses, universities, state and local governments, and the federal agencies. FLC promotes the transfer of science and engineering results

from federal laboratories into applications in the private and public sectors by creating a friendly environment for technology transfers. FLC focuses on national initiatives that are beyond the scope of individual laboratories, departments, or agencies. They develop and test transfer methods; address barriers to the process; highlight successful efforts; provide training and emphasize national initiatives where technology transfer has a role.⁵ DOD laboratory involvement has been noticeably modest in FLC activities.

National Technology Initiative. NTI was launched by presidential initiative in early 1992, 14 regional conferences were held across the nation during the year. NTI's main goal was to promote U.S. technological competitiveness by increasing the effectiveness of industry/government partnerships. Each conference addressed specific, regionally significant areas of technology and included exhibits staffed by federal agencies, universities, and laboratories.⁶ These conferences gave federal agencies a high-visibility way to reach and tell industry what federal technology transfer was all about and how industry could participate.⁷ They also addressed financing research, licensing agreements, and cooperative agreements between government and industry. This is under review by the current administration which, at this juncture, may be planning something more comprehensive under Vice President Gore's direction.

Cooperative Research Agreements

A survey of over 100 directors of 50 mid-sized and large commercial laboratories in 1992 concluded that industry's greatest potential for using federally developed technology is through cooperative research programs. These ventures include cooperative research and development agreements (CRADAs) and R&D consortia.⁸

CRADA. A CRADA is a legal agreement that implements

the new authority specified in the Federal Technology Transfer Act of 1986. CRADAs include agreements between one or more federal laboratories and one or more nonfederal parties under which the laboratory provides personnel, services, facilities, equipment or other resources, with or without reimbursement. The nonfederal parties provide funds, personnel, services, facilities, equipment, or other resources toward the conduct of specified research or development efforts consistent with the missions of the federal R&D activity. The term does not include procurements, grants, or other types of cooperative agreements made under the authority of any other legislation. A CRADA typically has to be renewed every year, which gives participating parties a means of terminating the agreement. CRADAs are usually terminated if the work has been accomplished or if any of the involved parties are not satisfied with progress or the arrangements. Industry and federal agencies had signed 1,360 CRADAs by the end of January 1993 and several hundred more were in negotiations.⁹

CRADA effectiveness is extremely difficult to determine. Successful transfer of technology should result in new marketable products, increased productivity, more patents, and overall industrial growth. Essentially no data exist to objectively assess CRADA effectiveness. Bruce Mattson, head of the office that works with intellectual property rights, CRADAs, licensing agreements, and disclosure statements for the National Institute of Standards and Technology (NIST), suggested that possible interim metrics for "perceived" success of CRADAs could be the number renewed each year as well as the number of return customers. Though not a quantitative measurement of how well technology has been transferred and incorporated for commercial purposes, these metrics can be a valuable indicator. A company would most likely not renew a CRADA if its experience was bad, or if it did not benefit from the arrangements. As the CRADA program matures and as government and industry gain experience with CRADAs, more definitive data will become available to assess CRADA effectiveness.

Consortia. These agreements include participation by multiple federal and nonfederal groups working on a common R&D goal, which often requires interdisciplinary approaches. Participants are representatives of government, industry, and academia, blending the spectrum of activities from theoretical research to full-scale manufacturing. Consortia funding may be shared but depends on the arrangements agreed by all participants. To tackle the more complex interdisciplinary problems, the consortium approach offers the greatest advantages. The trend will be toward a multiplication of consortia-type activities as their success and subsequent popularity increase with time. CRADAs and consortia are ideally suited to carry out the objectives of DOD's new acquisition strategy, as observed in a number of federal organizations that maintain close relationships with industry.

Making Swords and Plowshares

Several federal organizations are noted for their ongoing or recent successes in contributing useful technologies to the commercial sector. They are the Defense Advanced Research Projects Agency (DARPA), the National Institute of Standards and Technology (NIST), and the Air Force Office of Scientific Research (AFOSR).

DARPA. DARPA's mission is to exploit high pay-off, high-risk technologies with an emphasis on military applications. DARPA was created in 1958 as the Advanced Research Projects Agency to pursue basic and applied R&D for the military's use in promising weapon systems.¹⁰ The agency tries to stimulate, develop, and demonstrate technologies that can cause fundamental changes in future military systems and operations. DARPA targets areas for timely transition to weapon capability through specially designed prototypes, technology demonstrations, and manufacturing processes key to fostering a robust industrial base.¹¹

DARPA emphasizes dynamic technologies that are changing too fast to be captured adequately by traditional research and development practices. Their current main thrust is in the development and exploitation of information sciences, stressing solid state microelectronics, scalable high-performance computers, decision support systems, and integrated design and manufacturing. Other areas of effort are simulation, advanced materials, sensors, and manufacturing processes. An example of DARPA's success was the initial development of the electronic mail network that is fast becoming the world's main means of rapid and inexpensive communication.

DARPA funds research in universities (about 16 percent of their \$1.6 billion for FY1992), government laboratories (11 percent), and industry (60 percent), with an absolute minimum of administrative layering through a horizontal organizational structure. Program managers are free to pursue technologies they perceive as promising and have attained a great deal of success throughout a spectrum of activities. DARPA is also authorized to enter into contractual arrangements as full partners with industry, receiving royalties and other the rights of a company and accepting corporate obligations. This flexibility provides a fertile research environment for creative thought, industrial collaboration, and technology transfer for commercialization. During the 1980s, however, DARPA was forced to tie its programs more closely to military objectives and shift its efforts toward applied research.¹²

DARPA's strategic vision of long-term, high-risk technologies and subsequent success in developing such technologies as computing, simulation, and virtual reality have attracted the attention of industry and federal policymakers. Congress wants to extend DARPA's charter

TABLE 1.1 □ CRADA ACTIVITY FOR NIST (1988–92)

Fiscal year	1988	1989	1990	1991	1992
Newly signed	5	37	40	62	82
Total active	5	42	80	110	168

to address technologies of commercial interest. The Defense Authorization Act for FY1993 suggested renaming DARPA to Advanced Research Projects Agency (ARPA) to reflect increased emphasis on dual-use technologies. Its budget was increased from \$1.6 billion to \$2.4 billion for FY1993 with the additional funds to be programmed for industry's use to help commercialize dual-use technologies. DARPA's success also influenced Congress's decision to form the Advanced Technology Program (ATP), a civilian "mini-equivalent" to DARPA, under the direction of the Commerce Department.

NIST. NIST's relationship with industry has historically been very close and promises to be even closer in the future. NIST had its beginnings back in 1901 as the National Bureau of Standards, with a charter to establish standards for industry that would ensure new and evolving products adhered to certain common conventions.¹³ Hence, the gap between NIST workers and industrial researchers has been narrow and the cultural barriers confronting NIST personnel are not as great as those facing several other federal agencies. The Omnibus Trade and Competitiveness Act of 1988 further expanded NIST's role in the transition of technology into the private sector.¹⁴ One would expect, therefore, significant gains could be made in developing successful technology transition efforts between NIST and industry, provided that NIST's approach is sufficiently

proactive. That is exactly what has occurred.

One of NIST's first steps was to enter into CRADAs with organizations from the private sector.¹⁵ NIST's success in overcoming cultural barriers is demonstrated in the growth of their CRADA program, as shown in Table 1.1.¹⁶ These data show remarkable growth in number of new CRADAs each year and a substantial increase in the number of active CRADAs. This signifies at least early-on "satisfaction" of the customer.

NIST's success can be attributed to a number of factors. Among these are:

- harmonious working relationship with civilian institutions
- little work performed is classified
- efficient procedures to handle agreements
 - NIST requires only eight weeks to sign a CRADA
 - Only three signatures are needed to implement a CRADA.
 - Legal personnel work directly with the scientists.
 - Scientists need only execute a simple and easy-to-read CRADA form.
- Guest researchers are invited to NIST to work directly with NIST scientists.
- Scientists and engineers typically receive 30 percent of invention royalties.

The trend is for more consortia, which requires at least two partners from outside of NIST. Of the 1992 CRADAs, 54 percent consisted of multi-industry consortia. (A detailed

description of the NIST technology-transfer program is highlighted in the February 1992 issue of *Cooperative Technology RD&D Report*.¹⁷

AFOSR. Directed by Dr. Helmut Helwig, the Air Force Office of Scientific Research is committed to transferring technology to the industrial sector. AFOSR's mission is to fund and manage Air Force research activities conducted within academic institutions, private industry, and Air Force laboratories. AFOSR's major R&D objective is to provide the necessary basic research for its primary customers, the Air Force laboratories. AFOSR is currently helping these laboratories to define and structure their technology-transfer programs.

To maximize technological information exchange, AFOSR manages a number of "people-focused programs."¹⁸ Three of them are designed to enhance both collaborative research efforts and communication among professional scientists and engineers through temporary duty assignments. The Window on Science program brings foreign scientists to the United States to contribute to and participate mainly in Air Force-sponsored research projects. In other "window" programs, Air Force scientists conduct research for up to 179 days in other laboratories in Europe and the United States. AFOSR also sponsors a number of graduate and postgraduate fellowships to promote communication and understanding among a broad spectrum of research establishments. These exchange programs have resulted in a number of contracts and grants, with primary benefits going to federal laboratories. The resulting cooperative R&D efforts, however, will be beneficial to both sectors, especially in the long term.

AFOSR is working with Air Force Materiel Command to develop a new regulation on the conduct of Independent

Research and Development (IR&D) programs within industry. Part of the funding on Air Force development contracts is earmarked for contractor-directed IR&D. Historically, Air Force researchers reviewed and evaluated IR&D efforts for its applicability to Air Force R&D interests. With the recent emphasis on dual-use technologies and commercialization of DOD-sponsored research, contractors no longer have to spend IR&D funds on Air Force-directed problems. This change in philosophy presents an ideal opportunity for Air Force researchers to interact and collaborate with their industrial counterparts on commercialization of DOD-developed and -sponsored research. Hence a new regulation is needed on Air Force-sponsored IR&D efforts. In addition, Army and Air Force efforts are underway to revise AR 70-57 and AFR 80-27, which provide guidance for each service's technology-transfer programs.

AFOSR works with the Army Research Office and the Office of Naval Research to coordinate their research activities. All three of these organizations perform a similar function within their respective services. Their mode of operation and proactive activities with industry and universities provide a military example for government laboratories to look into.

Outlook for the 1990s and Beyond

The future economic well-being and national security of the United States are based on its industries' ability to compete. Industrial strength is in turn based on technological competitiveness, from basic research through manufacturing to marketing. Many recent reports and testimonies before Congress call for a closer linkage between federal laboratories and industrial firms to increase government contribu-

tions to industrial innovation. In September 1992, the House held a hearing on the National Aeronautical Research and U.S. Competitiveness Act of 1992.¹⁹ Afterwards, a bill was introduced and referred to the Committee on Armed Services to increase cooperation between DOD research and production facilities and U.S. industry.²⁰ The bill, known as the Federal Defense Laboratory Diversification Program, states that DOD production and research facilities lack incentives to carry out cooperative development activities with private industry. In addition, industry has too little opportunity to provide input into DOD research related to dual-use technologies. The diversification program is intended to promote coordinated DOD and industry development and application and transfer of dual-use technologies for commercialization. In addition, the bill will require development of laboratory benchmarks and metrics to assess transfer effectiveness. Each laboratory is expected to allocate at least 10 percent of its budget to cooperative efforts and set up an industry and academic advisory panel to oversee research plans and the implementation of this act. Unless the federal agencies develop a unified technology policy that includes an effective technology-transfer program, Congress will continue the "band-aid" approach by directing specific actions.

Recommendations and Summary

To regain its technology lead and increase its future economic competitiveness, the United States must take immediate action in five areas.

First and most important, the U.S. government must develop a well thought-out, overarching national technology policy and implement a complementary technology plan. This plan should address: R&D metrics; government and

industry relationships; long-term funding strategy; critical thrust areas for concentrated efforts; integrating DOD and other government agency R&D efforts and creating a forum to set R&D priorities; and developing parameters for foreign technology development and transfer policies. The plan must require proactive participation from all levels within the federal sector, including both the executive and legislative branches of government.

Second, the government needs to reduce perceived and actual red tape that discourages industries and government agencies from signing cooperative agreements. The bureaucracy associated with administering personnel exchanges between government and nongovernmental organizations and the formulation of CRADA arrangements should be streamlined. The NIST-CRADA process could be considered as a possible model for use by DOD and other government agencies.

Third, as part of a national technology plan, the government should establish a joint industry, university, and government forum to help set government R&D priorities and delineate federal roles and responsibilities related to dual-use technologies. Instead of being customers for federally developed technology, industry and universities should be partners in planning and executing technology programs. To force a long-term perspective, the government needs to consolidate its R&D, rearrange R&D priorities, and revise the value it assigns to technology. Concerted efforts should be focused on generic precompetitive research of long-term interest to the United States and U.S. industry. Centers of excellence should be identified among the federal laboratories to prevent duplication and ensure a critical mass in essential research areas. A restructuring of the federal laboratory system is in order. Elimination of

excessive duplication may provide an opportunity to streamline the laboratory structure for increased efficiency.

Fourth, the government should promote critical government and industrial R&D through efficient and practical cost-sharing arrangements. The government should exploit the advantages of groups that direct research, such as ARPA for DOD and ATP for DOC. The recently established ATP should be expanded and its funding substantially increased to foster generic research and the initial stages of applied research. Small business firms should be targeted for cooperative arrangements and cost sharing to encourage spinoffs from industry, universities, and government laboratories. Such relationships make technology transfers more efficient.

Fifth, the United States should maintain the current level of R&D spending as an investment for the future. Federal laboratories should strive for dual-use technologies, where appropriate, but not at the expense of DOD and space research needed to maintain technological superiority. During a slow economic period, government must resist the temptation to cut back R&D. Instead, government should offer industry tax incentives to long-term R&D investments. Congress should also commit to multiyear R&D efforts rather than yearly renewal cycles so that participating industry and government laboratories can maintain stability in their R&D programs.

In summary, successful technology transfer between organizations depends on good matches between technology producers and users. Immediate benefits from recent transfers are limited, but long-term gains will result from the relationships forged through cooperative research.

Government's proper role in these ventures is to provide the technology vision through an overarching national technology policy. It should provide the framework and the environment to encourage technological innovation and promote industrial growth. Industry, as the generator of the nation's wealth, must devise more efficient approaches to managing assets, stimulating creativity, and delivering innovation to the marketplace. Exploiting federally developed technology is only the beginning.

NOTES

1. Jeff Bingaman, Statement before the Senate Committee Hearing on Energy and Natural Resources, *Department of Energy Critical Technologies of 1991*, S-979, 102d Cong., 1st Sess., 27 June 1991, p. 24.

2. *Technology Innovation*, Chap. 63, U.S. Code Annotated Title 15, Commerce and Trade, prepared for: The Federal Laboratory Consortium for Technology Transfer (St. Paul, Minnesota: West Publishing Co., 1991).

3. Lorin Schmid, "The Federal Laboratory Consortium for Technology Transfer, Annual Report for 1990," presented to the House Committee on Science, Space, and Technology, 102d Cong., 1 Sess., *Transfer of Technology From Federal Laboratories*, no. 37, 30 May 1991.

4. *Federal Technology Transfer Act of 1986*, P.L. 99-502, 20 October 1986.

5. Lorin Schmid, "Annual Report for 1990."

6. A summary of the first 10 conferences is presented in their October 1992 report, which also includes a synopsis of other federal organizations geared to foster transfer of technology from the federal sector. The first 10 conferences attracted over 350 participants on average, and attendance increased at successive meetings.

7. *National Technology Initiative Summary Proceedings*, a report prepared by several federal participating agencies summarizing the first 10 NTI conferences held during 1992, published in October 1992. NTI point of contact is Matthew Heyman, with the National Institute of Standards and Technology, Department of Commerce.

8. J. D. Roessner, "Patterns of Industry Interaction with Federal Laboratories." Paper presented at the annual meeting of the American Association for the Advancement of Science, Boston, Mass., 13 February 1993.

9. Walter Baer, "Technology Transfer from Federal Laboratories to Industry: Promise and Reality." Introductory remarks presented in the Section of Industrial Science at the annual meeting of the American Association for the Advancement of Science, Boston, 12 February 1993.

10. John A. Alic, et al., *Beyond Spinoff, Military and Commercial Technologies in a Changing World* (Cambridge, Mass.: Harvard Business School Press, 1992), 137-38.

11. Secretary of Defense Dick Cheney, *Annual Report to the President and the Congress*, (Washington, D.C.: GPO), February 1992), p. 111.

12. A. Markusen, "Dismantling the Cold War Economy," *Technology Review* (April 1992), p. 26.

13. Alic, *Beyond Spinoff*, p. 48.

14. *The Omnibus Trade and Competitiveness Act of 1988*, P.L. 100-418, Sec. 5101, 23 August 1988.

15. "GM's Jack Simon, NIST's Dave Edgerly on the Technology Transfer Relationship," *Technology Transfer Business* (Fall 1992), p. 20-22.
16. Discussions with Dr. Bruce Mattson, Head of NIST's technology-transfer efforts including intellectual property rights, CRADA formulation, licensing agreements, and disclosure statements.
17. Grant Stockdale, Publisher, *Cooperative Technology RD&D Report*, no. 2 (February 1992), pp. 8-18.
18. Discussions with an AFOSR scientist. 22 October 1992.
19. Subcommittee on Technology and Competitiveness, House of Representatives, "National Aeronautical Research and U.S. Competitiveness Act of 1992," H.R. 5521, 15 September 1992.
20. S.3360, "Federal Defense Laboratory Diversification Program," 102d Cong., 2d Sess., 6 October 1992.

2

The Defense Acquisition Challenge: Fielding Affordable Weapons

ROBERT N. GAMACHE

ABSTRACT

The U.S. defense establishment is committed to fielding technologically superior but more affordable weapon systems. Faulty requirements generation and premature technology transition are the two most important causes of cost growth in U.S. defense acquisition programs. Associated issues are examined in this chapter and recommendations are made for improving the processes used by technologists, operators, and acquisition professionals to initiate major weapon system development programs.

In 1992, the Department of Defense (DOD) announced a new Science and Technology (S&T) strategy¹ to reduce defense procurement budgets in the new post-Cold War national security environment. This new S&T approach contained many of the resource strategy elements proposed earlier by Representative Les Aspin.² Under either approach, force modernization improvements will occur less frequently. Technology will be matured through successive generations in the laboratory before entering the formal acquisition "pipeline." Technology "rollover" is emphasized, and limited numbers of operational prototypes rather

than high-volume production are planned. No changes were made to improve the acquisition process itself. However, the Director of Defense Research and Engineering (DDR&E) was given more authority to exert centralized control over the defense S&T program. In theory, the DDR&E will use this authority to eliminate duplication among the military services.

The new S&T strategy is a step in the right direction—but not far enough. A more comprehensive approach should be taken—one that improves the weapon system acquisition process itself. From a program execution standpoint, this means elevating the importance of cost control. This imperative must be put on an equal footing with expanding the performance envelope of U.S. weapon systems. It also means improving the way major defense acquisition programs start and active management of the structure of the defense industrial base. A "dual-use" economy should be the goal—a single, integrated industrial base that produces globally competitive commercial and defense goods. This more comprehensive strategy complements the plan to improve the DOD S&T program by fixing the downstream problems in the acquisition pipeline. As a result, technologies that emerge from multiple "rollover" iterations will be fielded in less expensive weapon systems and on a shorter development cycle.

A companion paper³ examines seven cost drivers judged to be among the leading sources of cost growth in modern weapon systems (Table 2.1). These drivers are ranked by their relative impact on cost. A generic acquisition category is indicated in column three. The remaining column shows that the DOD S&T strategy partially addresses one leading source of cost growth—premature technology transition. Ideally, every program acquisition strategy

TABLE 2.1 WEAPON SYSTEM COST DRIVERS

Cost driver	Cost impact priority	Acquisition strategy category	Addressed by S&T strategy
Ineffective program leadership	1	Program execution	No
Compartmented product development	2	Program execution	No
Inadequate planning discipline	3	Program execution	No
Faulty requirements generation	4	Program initiation	No
Premature technology transition	5	Program initiation	Partially
Excess capacity	6	Industrial base	No
Low productivity growth	7	Industrial base	No

should address each of these cost drivers.

In this chapter, the relevant issues associated with the requirements generation and technology transition processes are explored in detail. These two processes must be fixed in order to take the output of a technology "rollover" program and establish a cost-effective weapon system acquisition program. In the discussion that follows, ten policy recommendations are offered for consideration by senior acquisition decisionmakers (Table 2.2).

TABLE 2.2 □ WEAPON SYSTEM AFFORDABILITY STRATEGY (Program Initiation Issues)

Cost driver	Policy recommendation
Faulty requirements generation	<ol style="list-style-type: none"> 1. Program initiation sequence 2. Requirements generation personnel 3. Requirements planning resources 4. Acquisition planning resources 5. Requirements-acquisition interface
Premature technology transition	<ol style="list-style-type: none"> 6. Technology exploitation approach 7. DOD S&T strategy revision 8. Technology-acquisition relationship 9. Technology-operator relationship 10. Industry-led technology development

Program Initiation Issues

Serious problems beset the start up of defense acquisition programs. Why? More often than not, the "true" mission requirements and costs have not been adequately identified, and a realistic acquisition strategy has not been developed. Hence, right from the beginning, most programs are poorly postured to meet performance goals on time and within budget.

To get programs on track, two broken processes need repairs (Table 2.2). The first order of business is to gain control over the requirements generation process. The second challenge is to implement a workable technology transition process—one that releases mature technologies at the proper time.

Faulty Requirements Generation

Defense contractors clearly see the breakdown in the requirements process. Many defense industry executives have expressed concern over the government's inability to

define reasonable and stable weapon system requirements.⁴ This problem is most acute at a program's initiation and continues throughout the development stages. Sometimes contractors are frustrated by having to act through a program office instead of dealing directly with end users.⁵

In theory, DOD Directive 5000.1⁶ and DOD Instruction 5000.2⁷ define an integrated management framework for maintaining effective interfaces among three DOD decision-making systems: the Requirements Generation System, the Acquisition Management System and the Planning, Programming, and Budgeting System (PPBS). These guidance documents also specify an event-driven acquisition process in which mission needs, alternative concepts, and affordability goals evolve into system-specific requirements, a stable design and a unit cost.

The first decision milestone, Milestone 0, is the initial interface between the requirements generation and acquisition management systems. Prior to this event, the requirements generation community—primarily military operators and users—have projected a deficiency in mission capability and validated a material need. Milestone 0 approval allows a small cadre of acquisition professionals to conduct concept exploration studies and provides authority to budget for a new major program. During this phase, the user helps evaluate the potential material alternatives and establishes minimum acceptable requirements for key system parameters.⁸ The next milestone, Milestone 1, grants approval to demonstrate and validate competing design approaches for the selected concept.

This process appears sound on the surface, but adequate acquisition planning information and resources are lacking at Milestone 0.⁹ Without adequate resources, mission area needs analyses are limited and generate few viable alterna-

tives. After Milestone 0, the planning resource shortage creates a serious mismatch between the output of the requirements process and the needs of the budget process. "Budget supportable" programmatic information does not exist. This causes immature program cost and schedule information to flow into the PPBS. Ultimately, it "locks" the program into a premature single solution.¹⁰ This problem is compounded when personnel without "hands-on development experience" specify detailed system performance requirements¹¹ in an Operational Requirements Document.

The ability to evolve requirements, manage program risks, and define an executable program is a direct function of manpower and funding resources. If a process is not in place to bring on the right numbers and types of personnel, the initial direction of the program will be determined by an inadequate program office cadre or an unqualified service headquarters staff. Experienced military officers—users with an operations research background and acquisition professionals with development expertise—are the critical manpower resources that must be made available at program initiation.

Weapon system acquisition risk can be greatly reduced by improving control over the interface between the requirements generation and acquisition management systems. Corrective actions should be taken in the following five areas.

1. **Program Initiation Sequence.** Amend DODD 5000.1 and DODI 5000.2 to identify Milestone 0 as approval to develop a proposal to initiate a program. Initiate acquisition management planning (form SPO cadre) before Milestone 0. Milestone 1 is the program initiation decision. Harmonize PPBS expectations for detailed programmatic

information with output of concept exploration activities.

2. Requirements Generation Personnel. Improve expertise of service, CINC, and JCS personnel to perform mission area needs analyses by requiring formal operations research education.

3. Requirements Planning Resources. Strengthen the requirements capability of the operational commands and the CINCs. Allocate sufficient manpower and funding for this function—especially during the pre-Milestone 0/1 requirements definition phase. Provide resources to keep ORDs current through product development cycle.

4. Acquisition Planning Resources. Strengthen the early acquisition planning capability of the materiel and systems commands by allocating sufficient manpower and funds to form a new program cadre prior to Milestone 0 and a full-strength program office at Milestone 0 approval.

5. Requirements-Acquisition Interface. USD[A] should serve as vice-chairman of the JROC. The DOD acquisition community must have authority to challenge and accept (or reject) MNS and ORD requirements. Formalize a service [and joint] procedure for a program-specific exchange of planners between the operational and materiel commands on a temporary duty basis (three-month tours).

Premature Technology Transition

Another major source of program cost growth is early transition of an immature technology (Table 2.2). The results are entirely predictable when technologies with high development risk are adopted as the program baseline—an expensive technology development effort must be undertaken. This effort holds the rest of the program "hostage" until a technical solution is found. The root cause of premature technology transition can be traced to the role of technolo-

gists, operators and developers during program initiation.

The requirements generation process directed by DODD 5000.1 and DODI 5000.2 is a problem-oriented approach—an operational need is evolved into system requirements. However, a solution-oriented approach is also possible. A new technology can be exploited to yield a superior weapon system. The former approach is known as "requirements pull" while the latter is commonly described as "technology push."¹² The advocates of technology push" solutions—either from government or industry—tend to be the applied researchers, scientists, or technologists associated with the breakthrough technology. They proceed with an advanced technology demonstration effort to show that a technology is ready for a weapon system acquisition program. To implement a "technology push" solution, the technologists "lobby" operators to frame a concept-specific "operational need" and assign a high priority on an integrated priorities list (IPL). This course of action effectively circumvents the Milestone 0 event. Program initiation occurs at either Milestone 1 or 2 without the benefit of early involvement by "hands-on" developers.

The new DOD Science and Technology (S&T) Strategy¹³ attempts to reduce the possibility of premature technology transition through more rigorous development and demonstration of advanced technologies. Control of the defense technology program is centralized under the Director, Defense Research and Engineering. Seven major thrusts are established to provide technology "push" roadmaps for the department's applied R&D efforts. Emphasis is put on the use of prototypes and Advanced Technology Demonstrators (ATDs) to demonstrate risk reduction at the system, a subsystem or a component level of technology integration.

Despite the laudable goal of reducing technical risk through a rapid prototyping approach, the new strategy does not bridge the gap between the S&T community and the developers. To adequately manage program execution risk, the developers or acquisition community must help guide the formulation and conduct of the technology risk reduction efforts. These demonstrations should occur as a parallel effort in conjunction with Phase 0 Concept Exploration activities aimed at developing the program initiation proposal. A more direct, decentralized linkage between the laboratories and acquisition product divisions would greatly facilitate this interchange.

The risk of starting a development program with immature technology can be reduced through a disciplined transition process. In addition to the five recommended corrective actions, policy changes should be made in the following five areas.

1. Technology Exploitation Approach. Amend DODD 5000.1 and DODI 5000.2 to provide a structured program initiation approach for exploiting "technology push" solutions. Use acquisition personnel with hands-on development expertise to evaluate technical risk and alternative concepts. Military utility should be assessed by users with a formal education or training in operations research. Evaluate concepts with the aid of advanced models and simulations.

2. DOD S&T Strategy Revision. Limit centralized direction of the Defense Technology Program by the OSD staff to multiservice applications and interdisciplinary technologies. ARPA should continue to serve as the principal executive agent.

3. Technology-Acquisition Relationship. Direction of service-specific technology thrusts, transition roadmaps, and

programs should be further decentralized to the research and engineering centers within each service's materiel and systems commands. Technology program execution should still be conducted by the laboratories assigned to parent product divisions.

4. Technology-Operator Relationship. Service and joint operational commands should continue to conduct annual reviews to assess the potential military utility of technology thrusts, transition roadmaps, and programs. Effectiveness of the technology reviews could be enhanced by including acquisition personnel to represent developer's interests.

5. Industry-Led Technology Investment. Place greater emphasis upon industry-led technology efforts with government participation and funding share no greater than about 30 percent of the total effort.

NOTES

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2. Les Aspin, "Tomorrow's Defense From Today's Industrial Base: Finding the Right Resource Strategy For a New Era," *White Paper*, House Armed Services Committee, Washington D.C., 12 February 1992.

3. Robert N. Gamache, *The Defense Acquisition Challenge: A Strategy for Improving Weapon System Affordability*, ICAF ERP-93-RS5 (Washington, D.C.: Industrial College of the Armed Forces, May 1993), pp. 1-42.

4. Curtis W. Barbee, et. al., *Problems Encountered in Transition from Research and Development to Production: A Defense Industry Perspective*, ICAF 86-N-15 (Washington, D.C.: Industrial College of the Armed Forces, May 1986), pp. 1-0.
5. *Ibid.*, p. i.
6. DOD Directive 5000.1, "Defense Acquisition," 23 February 1991, Part 2, pp. 2-1 to 2-13.
7. DOD Instruction 5000.2, "Defense Acquisition Management Policies and Procedures," 23 February 1991, Part 4, Sec. B, pp. 4-B-1 to 4-B-7.
8. *Ibid.*, p. 4-B-5. The "minimum acceptable requirements for key parameters" are documented in the system's Operational Requirements Document (ORD). In turn, these values are incorporated in the Concept Baseline and the Test and Evaluation Master Plan as thresholds for the system. All of this is determined by the user at a relatively early stage (concept exploration) of the weapon system acquisition program.
9. Glenn A. Kent, *A Framework for Defense Planning*, RAND Report R-3721-AF/OSD (Washington, D.C.: RAND Corporation, August 1989), pp. 25-26. Two other studies identify a similar need for more adequate planning resources (funding and personnel) prior to this milestone: Thomas R. Ferguson, Jr., and Terrence J. Herz, "Requirements Planning," *Airpower Journal*, Summer 1990, pp. 4-18; and Leonard Sullivan, Jr., *Characterizing the Acquisition Process*, Defense Acquisition Study White Paper (Washington, D.C.: Center for Strategic and International Studies, January 1986), pp. C-1 to C-8.
10. Ferguson, "Requirements Planning," p. 10.
11. Sullivan, *Characterizing the Acquisition Process*, p. C-4.
12. Ferguson, *Requirements Planning*, p. 7.

13. Charles B. Cochrane, "DOD's New Acquisition Approach: Myth or Reality?" *Program Manager*, July–August 1992, pp. 38–46; Paul H. Richanbach, et al., *The Future of Military R&D: Towards a Flexible Acquisition Strategy*, IDA Paper P-2444 (Institute for Defense Analyses, Alexandria Va., July 1990), pp. 1–22; and Donald J. Yockey, "Defense Acquisition [White Papers]," *USD(A) Memorandum for Secretaries of the Military Departments*, May 20, 1992, pp. 1–24.

3

Testing: The Bridge to Success for the New Science and Technology Strategy

ROBERT W. CHEDISTER

ABSTRACT

The Department of Defense (DOD) began a new strategy in 1992 for exploiting technology by focusing on Advanced Technology Demonstrations (ATD) to prove military utility and technological maturity before beginning new weapon system development programs. DOD test personnel are key supports for bridging the gaps between new technologies and military utility in the recommended actions.

In early 1992, the Director of Defense Research and Engineering (DDR&E) embarked on a new Defense Science and Technology Strategy.¹ The new strategy seeks to exploit new technologies by focusing DOD efforts along specific thrust areas and by demonstrating the military utility and maturity of new technologies before they enter the formal DOD acquisition process. A central tenet of this new strategy is the use of ATDs to assess military utility and technological maturity before proceeding into development and procurement. How DOD test organizations and test personnel can help bridge the gap between proposed

new technologies and demonstrations of military utility with ATDs is the question answered in this chapter.

Test and Evaluation in the New Strategy

Test and evaluation (T&E) in defense system development and acquisition is structured to give decisionmakers data and analysis to help them manage the cost, schedule, and performance risks involved in developing a new weapon system. Test and evaluation is a technical management tool for measuring a system's progress on its journey from design board into users' hands.² When a new system is being developed, it is tested and evaluated against design specifications to insure that it can do what it is supposed to do. This is the "developmental test and evaluation" (DT&E) phase of a program. Subsequently, when the system is evaluated against users' needs, the process is called "operational test and evaluation" (OT&E). DT&E is generally considered more objective than OT&E.³

The new S&T strategy capitalizes on new information technology to involve the users, or warfighters, early in the process of developing technology with military uses. The new strategy focuses DOD S&T efforts along specific thrust areas of most pressing military needs. The strategy also employs ATDs to show that new technologies are mature enough to be included in future weapon systems. These ATDs allow national decisionmakers to reduce the technological risks involved in weapon development programs and give users an early assessment of a proposed system's military utility.⁴ Testers are the bridge between users and technologists or scientists when a new technology is proposed for military use.

T&E Opportunities

By design, the new S&T strategy has been separated from existing acquisition processes and controls. S&T efforts will be headed by DDR&E Thrust Leaders and Technologists, while acquisition efforts follow a separate chain of command and line of oversight. This separation will likely increase the distance between technology and end-user.

The new strategy suggests that technology may become the main determinant in the U.S. defense strategy-making process. This suggests that a new technology must be thoroughly understood and its performance capabilities demonstrated, before its inclusion in a new weapon system. The emphasis will no longer be on the urgency for capability, but on proving utility and demonstrating technological maturity. Test communities are major players in demonstrating military utility and technological maturity. Hence, they will be called upon to help establish the links between technological possibilities and military requirements by pushing technology through these demonstrations. Five things can be done to enhance testing efficiency: let test organizations run ATD programs; get testers to streamline and accept more test risk; form ATD teams as the vehicle for enhancing efficiency; let the testers help to decide when a technology is ready; and get users involved early, on the test team.

1. Let Test Organizations Run ATD Programs. The new S&T strategy says that the DDR&E thrust leaders have primary responsibility for guiding and overseeing the ATD programs, and that the programs will be executed by line managers in the services and agencies. An ATD can be proposed by any service or agency but will need the advocacy of the thrust leader. The leader will control the budget and have a large say in how the program is run.

Regardless of who exerts execution authority, a program office in a product division or a test team at the test center, testers must play a major role in the decisionmaking process. There are some advantages in allowing developmental test organizations, backed by streamlined product division offices, to execute some of the ATD programs. Test center facilities are already set up to run a technology program requiring a generic test-bed aircraft or vehicle, for example. Test teams already established would not need extra manpower and resources for unnecessary overhead or additional layers of bureaucracy. Consolidating ATD program execution at the test site could be the most economical alternative.

2. *Get Testers to Streamline and Accept More Test Risk.*

Project Reliance, an initiative to consolidate DOD facilities, has attempted to address redundancy in test facilities, but changes have been more cosmetic than substantial. The DT&E Steering Group has suggested that transforming T&E facilities into joint service facilities could realize significant economies. This has become a fundamental roles-and-missions conflict among the services and is addressed in General Powell's 1993 Roles and Missions report. All the separate service test facilities could be streamlined, consolidated, and standardized. For example, the six aircraft and weapons test ranges in California, Nevada, and Utah could be united and still remain capable of supporting the shrinking defense base and making the investments necessary to continue to support future testing.

DOD testers are in a zero-defect tolerance mode for acquisition development testing. They go to extraordinary effort and expense to ensure the success of a test event. The new emphasis on demonstration versus evaluation opens a whole new realm of opportunities for creative and

cost-efficient methods of testing. Careful selection of a limited number of test criteria and an acceptance of test event risks could make test capabilities' expansion much easier without increasing costs. It will be up to the testers to help translate cost-effective technology demonstrations into examples of military utility for decisionmakers. The emphasis on continuous and total system evaluation can be reduced to allow users to decide on utility based on a few demonstrations, with the understanding that test failures do not necessarily mean lack of technological value.

3. Form ATD Teams for Efficiency. A team of technologists, testers, scientists, and users should be formed for each ATD. Each team could combine laboratories, test centers, test ranges, and contractors into an integrated unit with clear lines of authority, responsibility, and accountability. The DDR&E monitor, users, and other decisionmakers would comprise a team which should not be judged on the success of a program, but rather on the efficiency with which the team demonstrates emerging technologies. Members of the team could be linked electronically when physical proximity is not feasible.

Insistence on completely independent operational test events, done by separate operational testers after developmental testers certify a system is ready, may be counterproductive to efficient advanced technology demonstrations. The role of operational test agencies (OTA) as spokespersons for ultimate users should change from operational testers to utility advisers. Instead of excluding OTAs from the new ATD process or complicating the process by separate testing, close cooperation in a combined effort is needed. The operational testers can add a more realistic and representative flavor to technical demonstrations and serve as a communication link between

technologists and warfighters.

4. *Let Testers Help to Decide When Technology Is Ready.*

Decisions on technological utility and maturity are always objectively measured and subjectively evaluated. The methods and results of tests to satisfy program objectives rarely please all participants, because the proponents and opponents of the technology are biased in their analysis of the demonstration. The most consistently objective participants are likely to be the testers, who have been trained to conduct fair and realistic tests. Hence, testers should be given the lead in planning the ATD roadmaps or planning schedules, exit criteria, and demonstration profiles. But because testers tend to want to keep on testing, the S&T community can play a key oversight role by deciding how much testing is enough. Users will have to decide on the military utility of the technology with less-than-perfect demonstrations and operational realism. The challenge for each ATD team will be to make the leap from a simulated or artificial demonstration to an operationally realistic utilization for users to assess.

5. *Get Users Involved Early, on the Test Team*

Evaluating an idea and projecting its utility into the future is always difficult. This new S&T strategy will ask warfighters to envision the military utility of a technology based on undefined threats and often unrealistic demonstrations. For this new strategy to be most effective, the end-users must be able to review developing technologies frequently and readily assess demonstrated utility. The use of synthetic environments to facilitate technology assessments will likely stretch ability to forecast utility and visualize specifics on system needs. These synthetic environments, or simulations, while desirable, will also be complicated and expensive. The best method of bridging

this gap is to assign users directly to ATD program teams. This will minimize the impact of having users work with artificial environments and will help them assess the value of the technology in question clearly and quickly. One pitfall in this approach is that users may lose their objectivity or operational relevance if they stay too long. Some OTAs currently "borrow" users for operational tests of new acquisition systems. This same approach may work for short and relatively small ATD programs. These users could be attached to the test organization for the demonstration assessments. This would maximize the integrated team approach and be the most efficient way to cycle new technology through the critical demonstration criteria, putting it into the hands of a representative end-user who knows the test/demonstration environment.

Conclusion

The new S&T strategy is based on the fly-before-you-buy philosophy. It has taken some of the early technological development out of the formal acquisition process to help ensure that military utility is demonstrated before the DOD invests scarce resources on new and advanced weapon systems. This strategy offers national leaders an opportunity to use talented DOD testers to help bridge the gap between technological development and operational utility. Testers can help push new technology to the field if they can help users determine when a technology is ready.

NOTES

- 1 . Director of Defense Research and Engineering. *Defense Science and Technology Strategy*, Pentagon, July 1992.
- 2 . Department of Defense, *Defense Acquisition*, DOD Directive 5000.1, Washington D.C., Government Printing Office, 23 February 1991.
- 3 . Department of Defense, *Defense Acquisition Management Policies and Procedures*. DOD Instruction 5000.2, Washington, D.C., Government Printing Office, 23 February 1991.
4. Charles B. Cochrane. "DOD's New Acquisition Approach." *Program Manager*, July–August 1992, pp. 36–46.

4

Technology Timeliness From a Soldier's Perspective

JERRY L. WIEDEWITSCH

ABSTRACT

Technological superiority never equates to warfighting superiority unless technically advanced weapon systems are fielded when soldiers need them.

The former Under Secretary of Defense, Donald J. Atwood, on 28 May 1992 summarized the Department of Defense's new acquisition strategy:

Our new approach places increased reliance on research and technology development to maintain our advantage. We are making greater use of technology demonstrators and prototypes in the development of new weapon systems, and not all new weapons will automatically go into production. We will incorporate new technology into a current system only when fully proven and there is genuine need for improved performance or reliability. Full scale production of new weapon systems will occur only when there is a definite need because of obsolescence or aging of an existing system and when it is proven cost effective.¹

The new acquisition strategy will succeed or fail depending on how well it meets users' needs. This chapter looks to recent history to prove this point.

At the onset of the Korean war, General Douglas MacArthur ordered the 24th Division to proceed from Japan to Korea on 30 June 1950. He ordered a small task force from the division flown into Korea ahead of the main body to engage the North Korean Army as quickly as possible. A small delaying force, Task Force Smith, part of the 1st Battalion, 21st Infantry, landed at Pusan Airfield on the southeast tip of Korea on 1 and 2 July, with Lieutenant Colonel Charles B. Smith in command. Colonel Smith's delaying force was sent forward to engage the enemy on sight. South of Seoul, the task force dug hasty positions on the night of 4 July and awaited the approaching North Koreans. Shortly after 08:00 on 5 July, the North Koreans appeared. The Americans stood until they had expended their ammunition, then retreated under fire, suffering heavy losses as they were overwhelmed.

This is T. R. Fehrenbach's account of what happened:

The enemy tanks were now only two thousand yards in front of the infantry foxholes and still coming. Bursting HE shells blasted into the tank column, spattering the advancing armor with flame and steel and mud.

"Jesus Christ, they're still coming!" an American infantryman shouted.

Colonel Smith now ordered the 75mm recoilless rifles to hold their fire until the tanks got within 700 yards.

Moments later, at 700 yards, both recoilless rifles slammed at the advancing tanks. Round after round burst against the T-34 turrets, with no apparent effect.

Alerted by this opposition, the tanks stopped and turned their machine guns on the ridge where the Americans had fired. The tanks fired their machine guns, ripping and clawing the hillsides. Suddenly, American soldiers dove for any cover they could find.

Lieutenant Ollie Connor, watching, grabbed a bazooka and ran down to the ditch alongside the road. Steadying his 2.36-inch rocket launcher on the nearest tank, only fifteen yards

away, Connor let fly. Nothing—the small shaped charge burned out against the thick Russian armor without penetrating. Angrily, Connor fired again, this time at the rear of the tank where the armor protection was supposed to be thinnest. He fired twenty-two rockets, none of which did any damage.²

There was nothing mysterious about the Russian T-34. It had been used against the German panzers in front of Moscow in the early 1940s. Some said the T-34 was the best all-around tank used in World War II. It could be stopped—but not with the obsolete equipment in the hands of the U.S. soldiers in Task Force Smith. Their weapons were useless against the enemy armor.

After World War II, the United States had developed improved 3.5-inch rocket launchers that would penetrate the T-34. But in competition with strategic battleships and long-range bombers for scarce dollars, the Defense Department decided not to place them in the hands of the American troops.³ U.S. military historians record this sad story as a dramatic American defeat.

The pattern of this first engagement was repeated during the following days. All combat elements of the 24th Division fought the enemy bravely; but their inferior weapons left no choice but to retreat or be annihilated.

As Fehrenbach's story clearly illustrates, there is an undeniable difference between laboratory research and fielded technology. No one would claim that North Korea was technologically superior to the United States in 1950. But the fact was, the North Korean soldiers had better weapons than the Americans of Task Force Smith. To soldiers in the field, at that time and place, the North Koreans had a clear superiority in their fielded-equipment.⁴

Ground Force Modernization

From a combat arms perspective, modernization is a key to strength. Consider first the tank. The M1A1 tank proved to be one of the stars of Desert Storm and is still considered one of the best tanks in the world. The Army has 8,000 M1-type tanks in the inventory, but only 1,500 are the latest M1A1 version. Because it was fielded in 1985, the M1A1 1970s' technology will be old by 1995 and obsolete by the year 2000.

The next upgrade, the M1A2, represents the state of the art in tank technology. The original plan, to produce only 62, has been modified by recent foreign sales of around 500 to Saudi Arabia and Kuwait, and an upgrade plan for about 400 more older M1s. This will keep the production base warm, but will not provide enough tanks to equip all U.S. forces with the newest equipment. Hence, in light of future budget cuts, there could very well be more M1A2s in foreign hands than in those of the U.S. forces.

A similar concern arises in the case of armored vehicles. The Army recently abandoned its modernization program of the future, the Armored Systems Modernization (ASM) program, due to cost. ASM was a program to modernize over 6,000 armored vehicles on one of two common chassis. This commonality was designed to improve warfighting capability through compatibility, survivability, force agility, and lethality. At the same time it was projected to save over \$10 billion in maintenance, training, testing, support, and parts stockage costs.

Except for the Advanced Field Artillery System (AFAS) and its accompanying Future Armored Resupply Vehicle-Ammunition (FARV-A), all other components have been

canceled or returned to the tech base. There is an alternative plan to use current system chassis to form a family of vehicles, but no other long-range modernization programs are currently funded.

With the demise of the Soviet Union and the quick victory in the Persian Gulf, too often the consensus in Congress and DOD is that the equipment in hand is "good enough" and modernization is not really urgent. Or, as Mr. Atwood told Congress:

With the end of the Cold War and the decline in world threat, the need to bring new systems into production is no longer as urgent. We do not need to produce weapon systems at the pace we did in the past. There is more time to reconstitute larger armed forces if and when they are needed. We speak of warning time in years, instead of days, when we look ahead for global threats that might require major reconstitutions.⁵

From the lack of long range modernization plans and the feelings of complacency exhibited by DOD and some members of Congress, it is questionable whether the best equipment will make it to the field anytime soon.

New Missions, New Challenges

Considering that the next military conflicts will be regional, the notion of a "lack of a threat" is wishful thinking. While the former Soviet Union does not pose a serious threat as an entity, its military equipment is readily available around the world, to Iran, Serbia, or anyone else. Not only has it been fielded throughout its surrogates but it is also now available at bargain rates to whoever has the hard currency to buy. This is not just the normal Foreign Military Sales (FMS) quality equipment but includes even the top-of-the-line T-80 tank and BMP 3 fighting vehicle. This equipment is equal to and in some cases better than what the United

States has fielded.

In addition, the reductions put in place by the Conventional Forces in Europe (CFE) Treaty, freed up as many as 10,000 tanks and 20,000 personnel carriers for sale on the world market. While some equipment may be older, new ammunition, add-on armor, and improved optics, including thermal technology, are all readily available for retrofit. Likewise, three former Soviet production plants are still turning out quality equipment.

Skeptics will argue that the Persian Gulf War proved U.S. technology superior. But the source of that superiority, the technological advantages in a ground war, quickly boil down to two key areas:

- superior vehicular fire control, including thermal optics
- superior munition penetration capability.

Had the Soviets sold their best ammunition and multispectral smoke to Iraq, U.S. capabilities would have been challenged, and more American soldiers would have been lost in battle.

Similarly, competing foreign tank technology has not lagged. A new generation of tanks comparable to the M1A2 is now available in the field through FMS: the French LeClerc, the German Leopard II (Step II), the British Challenger II, the Israeli Merkava III, and the Japanese Type 90. American soldiers can easily envision them advancing toward their positions in some foreign land while they are still equipped with M1A1s.⁶

With the current uncertainty in the Balkans and other former Soviet states, as well as the upgrades going on in the combat systems in the Middle East, believing that U.S.

soldiers won't see top-of-the-line equipment used against them in the next regional conflict is wishful thinking.

Technology Superiority and Timeliness

Technology must be timely to make a difference. Tactics and technological superiority determine an Army's effectiveness. Technology permeates all facets of military hardware and tactics, multiplying the effectiveness of our forces. For example, because technology assists in intelligence gathering, tactics provide location and time advantages, giving U.S. soldiers the element of surprise. The Gulf War demonstrated the advantage that technology can give soldiers. It also provided clear evidence of the high military losses suffered by an enemy unable to counter technology.

But technology is a perishable commodity. The rate at which technology is developed has increased dramatically over the past decade. New items used to stay new for many years. Today computerized design aids bring products into being faster than ever before imaginable. Much of the technology introduced today is dominant for only 30 months before the next generation enters the market. This rapid rate of technological change makes it imperative to maintain a sufficient investment in military research and development.⁷ Technological superiority does not equate to warfighting superiority unless new systems are fielded in a timely manner.

Recommendations

To make the new acquisition strategy work, the U.S. soldiers must be adequately represented on the Defense Technology Board.⁸ This bridge between R&D in the laboratories and soldiers in the field will help ensure that user-critical technologies will be fielded. While the new

acquisition strategy must make sense to the budget analysts who are fighting an economic war, the results must also make sense to soldiers in the field. Sensitivity to their concerns will go a long way in ensuring the success of the new strategy.

NOTES

1. *Defense Symposium on Industrial Preeminence for National Security*, AUSA Background Brief, no. 44, September 1992, p. 1.
2. This vignette is an edited version of a story told in T. R. Fehrenbach's book, *This Kind of War* (New York, N.Y.: Macmillan, 1963), pp. 100–102. The book is an excellent account of the Korean War and is recommended for more detailed reading.
3. Ibid.
4. Steven K. Conver, Remarks to the Army Modernization Roundtable, Raleigh, N.C., 23 July 1992.
5. Statement of the Deputy Secretary of Defense, Donald J. Atwood, before the House Armed Services Committee Subcommittees on Research and Development and Procurement, 28 April 1992.
6. Seminar Series on U.S. Defense Industrial Base Preparedness, sponsored by the Association of United States Army (AUSA) and the American Defense Preparedness Association (ADPA), Washington, D.C., September 1992.
7. William M. Mogan, *The Landpower Essay Series*, no. 92-2, June 1992, p.1.
8. The Defense Technology Board (DTB) was established to assist the Director, Defense Research and Engineering (DDR&E) in evaluating seven new technology thrust areas. New technologies and systems must

be approved by this board before they are allowed to move toward production. The Services and Agencies will regularly propose Advanced Technology Demonstrators (ATD) as part of their routine programming and budgeting activities. These will be evaluated, in terms of their potential military benefits and cost, their technical risk and their jointness across Services and mission areas. Current members of the DTB include the Service Acquisition Executives and a representative of the Joint Chiefs of Staff.

5

Defense Decision-Making Under a Technology-Maximizing Acquisition Policy

EDWIN R. CARLISLE

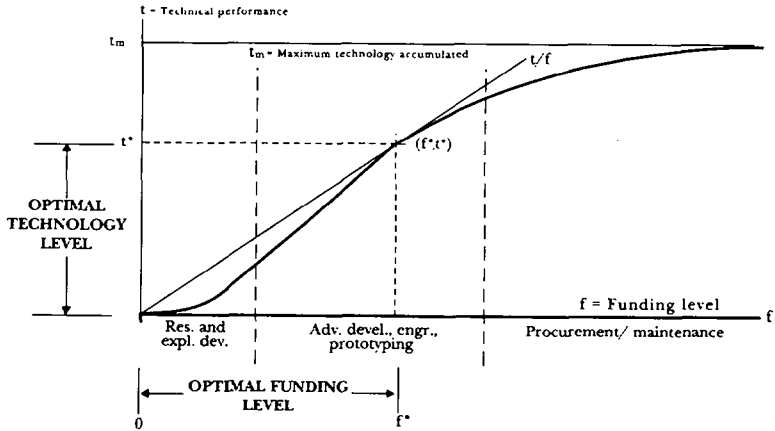
ABSTRACT

Defense planners should be aware of the tradeoffs inherent in a new acquisition strategy aimed at preserving technological supremacy. Forces can either optimize resources for mission effectiveness, or for technological maximization, but not both simultaneously. A rule of thumb, a decision rule, is derived for program managers and defense planners, should technology rather than mission become the target variable.

To reduce the probability that defense budget reductions will generate concomitant and perhaps irreversible reductions in the technology base, the U.S. Department of Defense (DOD) and the British Ministry of Defence (MOD) are revising their acquisition policies and funding priorities.¹ For fiscal year 1993, for example, the DOD allocated \$56.3 billion for procurement and \$38.5 billion for research and development (R&D), a 1.5:1 ratio.

Author's note: The author is grateful to A. Michael Higgins, Colonel, U.S. Air Force, for his valuable comments. Reprinted with permission from Defense Analysis, December 1992, pp. 309-12., with minor editorial revisions.

FIGURE 5.1 □ CUMULATIVE DEFENSE SYSTEM TECHNOLOGY PERFORMANCE CURVE



In contrast, during the last 30 years the ratio averaged 2.5:1 and has never before fallen below 2:1. If Congress concurs, the DOD will increase R&D expenditures by 2 percent a year, bringing the procurement-R&D ratio to 1:1 within five years.²

The overall objective of the new acquisition policy is to maintain the innovative capability and vitality of the defense technology base despite planned cuts in procurement. Procurement beyond prototyping and/or limited production runs is expected to be relatively rare. But funding for R&D will increase, and defense components, products, and systems will pass from development and engineering into production only after Advanced Technology Demonstrators (ATD), prototype testing, and other stringent criteria are successfully met.

Whenever procurement is aborted, the optimal level of program funding must be determined. This chapter derives a funding decision rule for program managers and strategic policymakers collectively responsible for maximizing the defense technology base.

Defense organizations pursue improvements in defense system performance to achieve technological preeminence, the basis for combat force multiplication. In Figure 5.1, the technological performance of a defense system is shown as a function of monies disbursed over the life of the system.

The amplitude of the technological performance (TP) curve, depicting cumulative technology for the last unit of currency disbursed, rises nonlinearly over the funding cycle because the efficiency of technology collection varies. Late in the funding cycle, procurement monies generate less and less technology per unit of currency because most research, development, and testing have been completed and, except for field evaluations, additional production runs add little to the accumulated technology. Hence the cumulative TP-curve rises asymptotically to total technology accumulation level (t_m) as the procurement stage matures.

Early in the funding cycle the reverse argument applies. Defense system acquisition cycles begin with basic research and exploratory development. The monies spent on basic research contribute little to technological performance compared to subsequent funding. One reason is that at the outset, research monies must be spent for laboratory space, new equipment, and support services which contribute indirectly and unevenly to system performance. Second, early scientific research tends to be broad-based and component oriented, for example, to extend the tensile strength of a material or to improve the thermodynamic or aerodynamic properties of a new component. Hence, scientific investigations may or may not provide technical information critical to defense applications, and the technical information may or may not be useful to the specific defense system under contract. Third, the usefulness of research relevant to a particular component or product often occurs in quantum jumps; hence, only after the expenditure of considerable time and money is the technological performance of the system actually realized. Subsequently, as the research and development portion of the cycle matures, the technological return to funding accelerates and the TP-curve begins to increase at a sharper rate.

The cumulative technology curve facilitates conceptualization of the following decision rule:

To maximize technology obtainable from a given budget, fund all programs into the development stage until the marginal technology benefit equals (no longer exceeds) the average technology benefit.

At any point on the TP-curve, the marginal technology benefit is the extra technology obtained from the last dollar spent (slope of the tangent of TP-curve). The average technology benefit is the total technology obtained divided by total funding (slope of a ray to a point on the TP-curve). The decision rule ensures programs will be funded to point (f^*, t^*) on the TP-curve, the point where ray (t/f) just strikes a tangency with the TP-curve.

The average technology benefit (t/f) measures the technological efficiency of program funding. As long as the marginal technology benefit exceeds the average technology benefit, the average technology benefit, and hence the technological efficiency of funding, will increase. Program managers will ensure maximum technological efficiency is achieved for each of the programs if they fund to point f^* , the point where marginal and average technology benefits coincide (f^*, t^*) and where the ray (t/f) is tangential to the TP-curve in the figure.

To strategic policymakers, the consequences of program managers' funding to (f^*, t^*) is technology base maximization. If each defense budget is fully expended on optimally funded programs, maximum growth of the defense technology base is assured.³

The decision rule maximizes technology by asking program managers to estimate whether the technology generated by the last dollar spent continues to exceed the program average. Although the rule assures that program funding becomes optimally efficient in the collection of technology, some of the efficiency gains are offset by new costs.

Opportunity costs of a technology-maximizing acquisition policy arise from adverse effects on defense firm managers and military planners. The new policy forces defense firm managers to downsize and puts pressure on them to operate more like independent research laboratories. The likely outcome is increased research costs, as in the case of firms that understate R&D costs to win contracts with the hope of recouping those costs during production. A second cost arises from defense firms that convert to civilian production. Long ago Melman⁴ argued what Gansler⁵ and other conversion advocates are arguing today: defense contractors should diversify into nondefense but commercially similar product lines. In his rebuttal of this view, Weidenbaum⁶ draws upon the "Grumman case," arguing that, historically, firms that have tried commercialization have generally not fared well. Defense firms that fail or weaken themselves trying to compete in a cost-rather than a performance-driven market add directly or indirectly to the cost of the government, offsetting some of the efficiency gains of a technology-maximizing acquisition policy.

Costs may also accrue to defense organizations. As one group of defense planners seek the benefits of a technology-maximizing policy, a second group concerned with the ability of defense firms to surge may be adversely affected. For example, many firms now warn that once assembly

lines and plants are closed and critical technical personnel are dismissed as a result of procurement cutbacks, reconstitution costs will be severe, and surge may be impossible.

Similarly, defense planners concerned with force mission capability may find their plans compromised. The ability of the force to execute its mission is not only impaired by budget reductions, but also by the change from a mission to a technology-strategic policy objective. Policymakers can maximize force funding with respect to mission or technology, but not both concurrently. Hence, a cost of technology enhancement may be mission impairment.

All costs noted diminish the efficiency with which defense technologies can grow as budgets decline. Although the decision rule remains valid, the decline in efficiency suggests the TP-curve, and hence the optimal funding level, will shift right. More funds will be needed just to maintain existing technical performance levels.

Clearly, the benefits from any new policy must outweigh the costs. Much has been written about the benefits expected from the new policy; now is the time to look at the specific costs.

NOTES

1. In Britain, the Ministry of Defence is undergoing a special revision of its own; see A. Clark. "High Technology Defence Industry: the Future." *Army Defence Quarterly Journal*, vol. 121, no. 4 (October 1991).

2. J. G. Roos. "Acquisition Policy is Fatally Flawed." *Armed Forces Journal International*, vol. 42, no. 1 (May 1992), p. 5.

3. The decision rule providing technology base maximization can be derived more succinctly. Given budget constraints (B), where (t) denotes technology obtained from funding (f), the total number of programs that can be funded is B/f. Hence, total technology accumulated for $t = t(f)$ is,

$$T = Bt(f)/f.$$

Differentiating for the first order condition:

$$T' = Bt'(f)/f - Bt(f)/f^2 = 0.$$

Assuming the second order condition confirms the existence of a maxima, one obtains the decision rule:

$$t'(f) = t/f.$$

4. S. Melman. *Pentagon Capitalism* (New York, N.Y.: McGraw Hill, 1970).

5. J. S. Gansler, "A Case for Dual-Use in Defense." *Washington Technology*, vol. 7, no. 1 (April 1992).

6. M. Weidenbaum, "The Future of the US Defense Industry," *Contemporary Policy Issues*, vol. 34, no. 1 (1992), pp. 27-34.

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