USAWC STRATEGY RESEARCH PROJECT

TRANSFORMING DEFENSE BASIC RESEARCH STRATEGY

by

LTC Augustus W. Fountain III
U.S. Army

Professor Leonard J. Fullenkamp
Project Advisor

U.S. Army War College
CARLISLE BARRACKS, PENNSYLVANIA 17013

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **03 MAY 2004**	2. REPORT TYPE	3. DATES COVERED **-**
4. TITLE AND SUBTITLE **Transforming Defense Basic Research Strategy**		5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S) **Augustus Fountain**		5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **U.S. Army War College,Carlisle Barracks,Carlisle,PA,17013-5050**		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR'S ACRONYM(S) 11. SPONSOR/MONITOR'S REPORT NUMBER(S)
12. DISTRIBUTION/AVAILABILITY STATEMENT **Approved for public release; distribution unlimited**		
13. SUPPLEMENTARY NOTES		
14. ABSTRACT **See attached file.**		
15. SUBJECT TERMS		

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**		**31**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

ABSTRACT

AUTHOR: LTC Augustus W. Fountain III

TITLE: TRANSFORMING DEFENSE BASIC RESEARCH STRATEGY

FORMAT: Strategy Research Project

DATE: 19 March 2004 PAGES: 31 CLASSIFICATION: Unclassified

Defense basic research is primarily concerned with the discovery and development of fundamental knowledge and understanding to enable future technologies that benefit national defense capabilities. Public funding of basic research for the DoD during the Cold War was successful because it minimized risk through taking maximum advantage of long term research projects that produced rather mature technologies for development. With a basic research budget less than half that of the National Science Foundation and a mere fraction that of the NIH, the DoD can no longer afford to pursue lofty science education goals and satisfy the DTOs and JWTOs necessary to meet the needs of future war-fighting. To demonstrate relevance, research programs, including unsolicited programs, must identify and prioritize individual research goals and demonstrate the linkages back to National initiatives or overall relevant research goals. Additionally, no single approach to funding basic research will be able to satisfy the tremendous technology needs of the future force. The ability of the DoD to leverage research within the university and industrial base is predicated on using government scientist to shape the basic research into key war-fighting technologies. Immediate action is necessary to reverse the funding and management trends at the Service Laboratories in order to recruit and retain the high quality, dedicated scientists and engineers necessary to conduct and manage cutting-edge research.

TABLE OF CONTENTS

ACKNOWLEDGEMENTS

I would like to thank BG Daniel J. Kaufman, Dean of the Academic Board at the United States Military Academy, and COL David C. Allbee, Professor and Head of the Department of Chemistry and Life Science, for giving me the opportunity to serve as the USMA Fellow to the U.S. Army War College this year. I also owe a debt of gratitude to the following members of The National Academies, Department of Military Science and Technology: Bruce Braun, Director, Board on Army Science and Technology; Michael Clarke, Director, Air Force Science and Technology Board; Robert Love and James Garcia, Senior Program Officers, Department of Military Science and Technology. They took considerable amount of their valuable time to educate me on the politics of funding basic research. I would also like to thank Dr. Joseph Rocchio, Director SEDD, U.S. Army Research Laboratory for detailing the role of metrics in evaluating basic research and explaining how the Collaborative Technology Alliances forged at ARL operate.

Most importantly I would like to thank my wife Cindy, who is by far the most important person in my world.

LIST OF ILLUSTRATIONS

TRANSFORMING DEFENSE BASIC RESEARCH STRATEGY

The United States Armed Forces currently enjoy an unprecedented level of technological superiority across the full spectrum of military threats. These advances were primarily funded through U.S. Government (USG) and Department of Defense (DoD) support of basic science and technology throughout the 50 years of relative peace experienced during of the Cold War. A long term investment in research has allowed the military to field key enabling technologies such as radar, jet engines, nuclear weapons, night vision, precision guided munitions, stealth, the Global Positioning System, unmanned air vehicles, and information management systems that have dramatically changed warfare. Technological superiority will continue to be a cornerstone of our national military strategy. [1] While today's technological edge allows us to dominate the broad spectrum of conflict and win with relatively few casualties, maintaining a technological edge has become a key component of the vision to transform the U.S. joint forces by relying on the development and fielding of high-technology weapons that enable a smaller force to be more effective.[2] The catalyst that created today's generation of technological advances was a post World War II decision to create a huge national engine of public science. The blueprints of this engine were drafted in a report to President Truman by Vannevar Bush, who was the Director of the Office of Scientific Research and Development. The foundation of Dr. Bush's plan was to fund investigator-initiated projects, largely conducted in academic laboratories, by civilians independent of the military establishment. [3] Under this construct, universities did "fundamental" research work; the "R" in R&D. Government laboratories and arsenals would then take some of that "R" and through the cooperation of industry develop it ("D") into military technologies. The vision Bush proposed clearly recognized that the applications developed from basic research often appeared many years after the work was initiated and that there may be no clear benefit realized from much of this work.

In the fifty years since the end of World War II, changes have occurred that might call for a major adjustment in strategy for defense funding of scientific research. The two most important are the end of the Cold War and the emergence of a global technological marketplace.[4] Public funding of basic research for the DoD during the Cold War was successful because it minimized risk through taking maximum advantage of long term research projects that produced rather mature technologies for development. The Global Positioning System (GPS) is an example of a technology that has given U.S. forces an incredible advantage on the modern battlefield. Research on satellites and a global positioning system began in 1946 after the publication of an article on geo-stationary orbits by physicist Arthur C. Clarke, more widely known for writing

“2001: A Space Odyssey.” The first GPS satellite was launched in 1978, with the full 24-satellite constellation completed on March 9, 1994.[5] In a way our science and technology capability acted as an additional form of deterrence against our adversaries. However in today’s fast paced and dynamic environment, the Department of Defense cannot afford 48 years to research, develop, and deploy critical technologies to the war-fighter. Many critical defense technologies are now readily available to the global market place. Therefore advanced technology is as readily available to adversaries and allies alike. This makes the in-house development of new capabilities ever more important.

The Department of Defense is relying on an investment in Science and Technology (S&T) to provide the foundation for transformational joint war-fighting capabilities. However, the DoD has maintained the same basic research infrastructure and funding policies developed for the Cold War. In order to stay ahead of adversaries with access to technologies available in the global marketplace, the DoD must shorten the time frame from concept to fielding. The public funding of defense basic research in universities is too cumbersome, slow, and focused on the wrong goals to adequately develop the technology needed for fighting the Global War on Terror (GWOT) or to deliver to the Future Force (2020). Thus the question posed by this paper, “Is the Department of Defense basic science research strategy capable of developing the technology necessary to enable key elements of the U.S. military’s transformation?”

DOD S&T PROCESS

The purpose of Department of Defense research is to ensure that our war-fighters have “superior and affordable technology to support their missions and to provide revolutionary capabilities.”[6] The DoD Science and Technology (S&T) program is coordinated and focused through a series of five documents : the Defense Science and Technology Strategy, the Defense Technology Area Plan (DTAP), the Defense Technology Objectives (DTO) document, the Joint War-fighting S&T Plan (JWSTP), and the Basic Research Plan (BRP). These documents, as well as supporting individual S&T master plans of the military Services and Defense Agencies, guide the annual preparation of the DoD budget and program objective memorandums (POMs). The first four documents are updated quadrennially with the later being updated biennially. The Defense S&T Strategy establishes high priority investment areas and then implements those goals by assigning a service or agency lead for a given research area. This process is called “Reliance” and allows the DoD to combine resources and reduce redundancy. The Reliance process includes research efforts from the three Services, the Ballistic Missile Defense Organization (BMDO), the Defense Threat Reduction Agency (DTRA), the Defense Advanced Research Projects Agency (DARPA), the Office of the Deputy Under Secretary of Defense for Advanced Systems and Concepts (ODUSD(AS&C)), and the Joint Staff (J-8). [7]

The Defense Technology Area Plan (DTAP) documents the focus, content, and principal objectives of the overall DoD science and technology efforts. The DTAP outlines the Applied Research (6.2) and Advanced Technology Development (6.3) investment strategy in twelve key technologies critical to the DoD, but organized along Service lines. Additionally the DTAP details the nearly 200 Defense Technology Objectives (DTOs) which are the fundamental building blocks of the Defense S&T program. These objectives form the basis of the Defense S&T Reliance process by assigning key research objectives and specific technology advancements to each of the participating services and agencies.[8]

The Joint War-fighting S&T Plan (JWSTP) is similar to the DTAP. However, it ensures joint efforts are achieved throughout the Applied Research (6.2) and Advanced Technology Development (6.3) arenas. This document outlines the Joint War-fighting Capability Objectives (JWCOs) which are similar in principle to the DTOs, but their primary objective is to ensure that the S&T Program supports future joint war-fighting capabilities. The Joint Requirements Oversight Council (JROC) has endorsed the planning process and methodology of the JWSTP. Together, the JWSTP and DTAP ensure that the near- and mid-term needs of the joint war-fighter are properly balanced and supported in the S&T planning, programming, budgeting, and assessment activities of DoD.[9] While the technical areas outlined in the DTAP and JWSTP are different, active participation by the Service laboratories, the Defense Agencies, and the war-fighters provides the requirements that drive the basic research areas. These requirements are evaluated in Service S&T Program reviews and the Deputy Under Secretary of Defense (S&T) Technology Area Reviews and Assessments (TARAs).

In the TARAs, representatives from academia, government, and industry evaluate programs based on their completeness, balance, relevance, transition plans, and thus avoid unnecessary duplication with other DoD programs. The TARAs also compare the programs to DDR&E guidance, the Defense S&T Strategy, the Joint War-fighting S&T Plan, the Defense Technology Area Plans (DTAPs), and the Basic Research Plan. Particular emphasis is placed on the responsiveness of programs to the DTOs, which state what technology advancements are to be developed and demonstrated; by what fiscal year; for what specific benefit; solving what technical barrier; and for which Service. As shown in Figure 1, the Science and Technology Planning Process is primarily used for the sole purpose of developing the POM. One criticism of this process is that there are no effective criteria for evaluating these programs in their ability to fulfill joint war-fighting requirements.[10] There simply is no mechanism in place to evaluate whether the investment of funding toward meeting joint war-fighting requirements is met until a technology is being fielding.

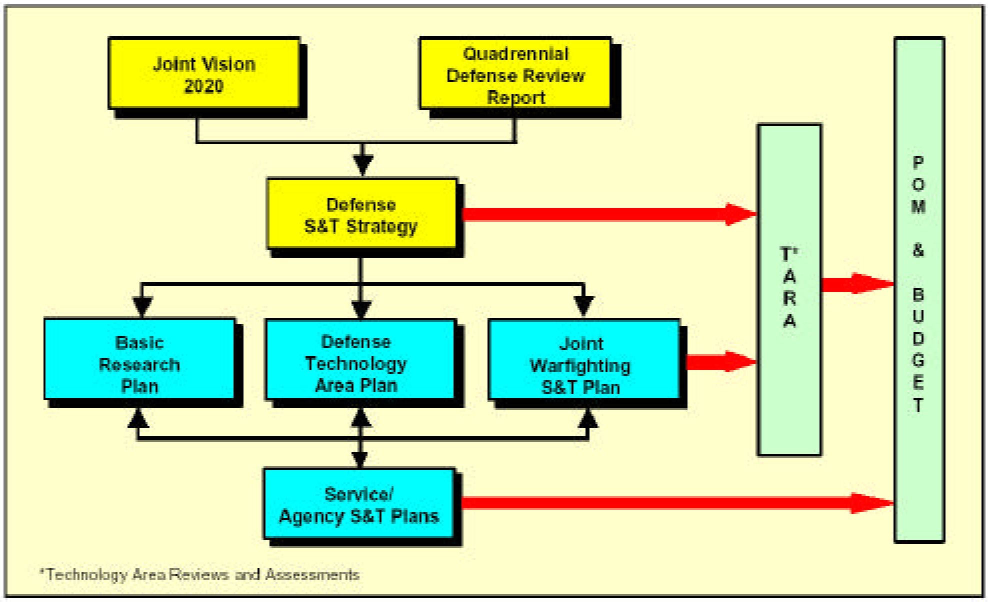

FIGURE 1: SCIENCE AND TECHNOLOGY PLANNING PROCESS[11]

DEFENSE BASIC RESEARCH

Basic research is primarily concerned with the discovery of new fundamental knowledge and the expansion of understanding in a given area. Defense basic research is therefore primarily concerned with the discovery and development of fundamental knowledge and understanding to enable future technologies that benefit national defense capabilities. The character of Defense basic research therefore is more distinguishable from other similar research more by the researcher and his or her motivation than by the actual research conducted.[12] The Basic Research Plan (BRP) presents the DoD objectives and investment strategy for DoD sponsored Basic Research (6.1) performed by universities, industry, and Service laboratories. The BRP supports the long term research needs of the DoD presented in each of 10 technical disciplines: Atmospheric and Space Sciences, Materials Science, Biological Sciences, Mathematics, Chemistry, Mechanics, Cognitive and Neural Science, Ocean Sciences, Computer Science, Physics, Electronics, and Terrestrial Sciences. While it is often difficult to delineate the boundary between basic research and applied research, basic research should enable many potential future applications and uses whereas applied research seeks to fill gaps in knowledge towards a particular application. Defense research is managed mainly by or through: the Army Research Office (ARO), the Office of Naval Research (ONR), the Air Force Office of Scientific Research (AFOSR), and the Defense Advanced Research Projects Agency (DARPA). Oversight of the entire Basic Research Program is the responsibility of the Director for Basic Sciences in the Office of the Deputy Under Secretary of Defense for Laboratories and Basic Sciences (DUSD(LABS)), located in the Office of the Director of Defense Research and Engineering (DDR&E).[13] While the DoD research, development, test, and evaluation (RDT&E) budget appropriation for FY03 is $57.0 billion, the amount budgeted for 6.1 (basic research) is $1.417 billion; or 2.49 percent of the RDT&E total.[14] As shown in Figure 2, this amount has remained nearly constant since 1985.

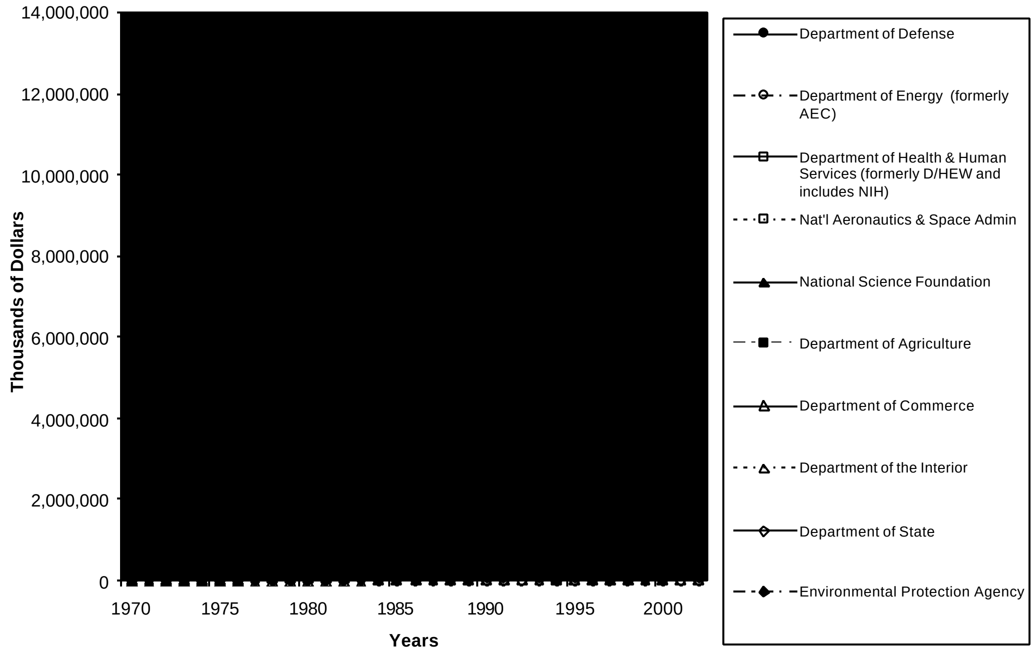

FIGURE 2: FEDERAL OBLIGATIONS FOR BASIC RESEARCH, BY AGENCY: FISCAL YEARS 1970-2002[15]

It could be questioned whether this investment in basic research is being made wisely. Nearly 54% of this funding goes to universities with no direct accountability to fulfilling requirements outlined in the DTAP. Instead of seeking to meet the technological needs of the war-fighter, much of this funding goes toward more altruistic goals such as: establishing collaborative research between university professors and students with military laboratories; strengthening academic programs in science, mathematics, and engineering; encouraging students to pursue degrees and careers in science; providing equipment, scholarships, and work/study opportunities; helping universities improve their capacity to perform research of interest to DoD; and training students in scientific disciplines.[16] However according to Dr. Joseph Rocchio, Director, Sensors and Electron Devices Directorate, Army Research Laboratory, this funding is crucial in order to "buy access" to the smartest minds and get them interested in helping the DoD solve important problems.[17]

Within academia, the peer review of proposals has long assured the matching of funding to researchers with the best ideas. Defense basic research is also carried out in a similar competitive process, by having individual researchers or research consortia submit proposals to receive funding in the form of research awards, education grants, equipment grants, and technical assistance grants. The Multidisciplinary University Research Initiative (MURI) program is the principal means of obtaining DoD funding for basic research. While peer review goes a long way toward ensuring quality in the allocation of funds from federal agencies to individual research projects, it normally occurs at the start of the funding stream with few checks on the quality of the research outputs.

If basic research were a business, the efficient allocation of resources would be a relatively straightforward matter. Resources would go toward the efforts that demonstrated the highest productivity, as calculated by some output metric. But measuring research outputs and the productivity of basic research is highly problematic and has proved a troublesome issue for businesses as well.[18] Basic research cannot easily be made deterministic, so it is often difficult to know if a project will be successful or proceed in the originally proposed direction. Presently there is no widely accepted way for the Federal government in conjunction with the scientific community to make priority decisions about the allocation of resources in and across scientific disciplines.[19] While metrics such as the number and quality of peer-reviewed publications, citations, graduate students, research awards, and level of external funding are indicators of a vibrant research program, they do not necessarily show how the needs of the war-fighter are being met. Without meaningful and practical output measures, the system of peer-reviewed individual research grants and institutional grants simply invests in the infrastructure and salaries necessary for researchers to do their work. The scientific work that proceeds from these investments should therefore meet some metric to ensure that the joint war-fighting capabilities of the future are being developed. Without some individual or institutional accountability of university researchers to the TARA process means, the allocation of funds through peer reviewed grants will not meet all the needs of our defense basic research program. This is evidenced by the fact that from FY97 - FY02, 181 MURI projects have been funded and none of them have transitioned technology to the war-fighting force.[20]

A Cooperative Research and Development Agreement (CRADA) is another way industry and universities partner with DoD to conduct specific R&D activities. Any state or local governments, commercial industry, public or private foundation, or non-profit organization can enter into a CRADA agreement with the DoD. A CRADA is not considered a procurement contract, grant, or cooperative agreement. A CRADA is a written agreement between one or more DoD laboratories or technical activities and one or more non-federal entities. The parties entering into a CRADA primarily exchange intellectual property, expertise, and data. However, they may also exchange the use of personnel, services, materials, equipment, and facilities. The DoD can also provide personnel, facilities, equipment or other resources, with or without reimbursement. Non-federal partners can provide funds, people, services, facilities, equipment, or other resources. DoD participants can accept funding from a CRADA partner to perform research or development that benefits the partner, but no DoD funds can flow to the CRADA partner. The rights to inventions and other intellectual property are flexible and are negotiated as a part of the agreement.[21]

An additional issue well beyond the scope here is the issue of Congressional earmarking. Public funding for defense basic research often becomes a political “football” due to the large institutional and regional economic stakes. In a recent survey, the National Academy of Sciences highlights the dramatic growth in the number and size of earmarks for academic research. Over the past decade, Congressional earmarks for academic institutions to conduct defense basic research have increased in value from the tens to the hundreds of millions of dollars.[22] An example are the six recent congressionally directed medical research programs signed into law by President Bush as an inclusion to the FY2004 Defense Appropriations Act. These programs earmark nearly $273 million dollars for research in the fields of breast cancer, prostate cancer, neurofibromatosis, ovarian cancer, leukemia, and tuberous sclerosis.[23] While these programs pursue worthwhile goals, none of these programs serve to meet the needs of the DTO or JWO and in no way serve the war-fighter. In this way the practice of Congressional earmarking is the least productive use of research funds. Congressionally earmarked funds generally place narrow constituent interests over scientific merit. The promise or threat to remove funding is often used to influence or change the character of a project. Additionally, these efforts often bypass the primary mechanism for allocating federal basic research funds;

the competitive, peer review process. Without a means of determining merit or need, Congressional earmarking for defense basic research further removes the researcher from any obligation of meeting the technological needs of the joint force. Since Congressional earmarks will in no doubt continue, it is therefore the responsibility of policymakers to ensure that necessary investments in defense basic research and institutional grants proceed on the basis of scientific merit and in the larger context of national needs and priorities.

While there is a need for public investments in university infrastructure and large-scale projects, the nature and size of defense research makes the funding of universities inappropriate. As shown in Figure 2, the amount of Federal obligations for basic research from the DoD are much smaller in comparison to those of the NIH, DoE, NSF and NASA. During the 1970's, industry recognized that university-centric research was too cumbersome and transformed their research efforts into something called "industrial-strength basic research."[24] In this construct, research is pursued within large interdisciplinary teams with impressive infrastructure support. In a recent interview, James C. McGroddy, who retired in 1996 as a senior vice president for research from IBM, stated that "industry can gain great benefits from research if it's managed right." Research, he argued, "cannot be performed in a monastery on a hill." When research is properly managed it "it attracts the best people, it moves basic science to invention to new technologies, which garner key patents, and the company also gains key insights into the future."[25] Teams working in a single corporate setting, with powerful capital tools and objective-driven management, have demonstrated that they can tackle big projects, often more successfully than distinguished but dispersed academic consortia. Industrial-strength fundamental research in biotechnology has been the most recent proving ground of this type of research and has generated revolutionary changes in short periods of time.[26] This concept is nothing new and is similar to the concept of the "Manhattan Project" that created the atomic bomb at the same time as making great strides in the field of high-energy physics.

DOD LABORATORIES

Vannevar Bush's vision of publicly funded research was primarily designed to maintain the high level of scientific and intellectual capital created during World War II and apply it toward "practical purposes." Having an educated work force with universities manned with capable researchers would create a scientific strategic reserve allowing the nation to surge in times of future war. However Bush also recognized that the technological margin of success enjoyed by the Allies during the war was dangerously thin and that there was a continued need for research to support national security. He felt that this research would best be orchestrated through "a civilian-controlled organization with close liaison with the Army and Navy, but with funds direct from Congress."[27] In addition to conducting research on its own, an organization such as this would be necessary to evaluate new technical opportunities regardless of their source, since some breakthroughs are bound to occur elsewhere. Today this "organization" is realized through the 700 laboratories and research centers known as the Federated Laboratory System.

Over the past 30 years there have been 100 major studies on the health of the government science and technology laboratories. Each of these reports has endorsed the requirement for world-class in-house service laboratories and has stated that these service laboratories are an essential component of the war-fighting machine of the United States. However, all of these studies state unequivocally that our defense laboratories have been left in a state of severe crisis. The two most recent studies of our Service laboratories are particularly damning. [28, 29] These reports state that our Service laboratories are so poorly funded and managed that "unless they receive help soon at the Service, Office of the Secretary of Defense (OSD), and congressional levels they will no longer be able to recruit and retain the high quality, dedicated scientists and engineers required to perform the research necessary to preserve our military's technological superiority."[30]

John H. Hopps Jr., Deputy Director of Defense Research and Engineering (DDR&E) and Deputy Undersecretary of Defense in the Department of Defense, in the same interview with James C. McGroddy, stated that our "defense laboratories should have the same attributes as our transformed uniformed military forces." While the DoD is transforming to build modular joint forces with the attributes of speed, agility, lethality, and knowledge, the Service laboratories need to transform with the parallel attributes of "productivity; responsiveness and adaptability; relevance, programming, and execution; generation and application; and perpetuation of knowledge." Hopps argues that this transformation should lead to an increased investment in breakthrough activities and increase the reach of the defense labs into university basic research programs.[31]

It is crucial that the focus on defense unique technologies be continued. If the character of defense basic research is truly defined more by the motivation of the investigator, then this form of research is best accomplished through Service laboratories and not universities or industry. An NRAC report argues that industry will only pursue high-profit major weapons systems, but "the laboratories are crucial to address high-risk, low-volume Science and Technology (S&T) projects."[32] These projects are often not profitable enough for industry to take on or are classified in nature so universities avoid them. However, like the atomic clocks pursued by the U.S. Naval Observatory that enabled the development of the Global Positioning

System, they are critical to the successful fielding of defense related enabling technologies. In addition to conducting research on their own, a vibrant system of Service laboratories is needed to provide in-house technical experts who can advise acquisition program managers (PMs) on the technical feasibility and affordability of commercial-off-the-shelf (COTS) or proposed outsource solutions.

In the "Science and Technology Workforce for the 21st Century" the senior steering group charged with investigating the health of the Service laboratories outlined the ideal state of a defense science and technology laboratory. According to this report, an ideal defense laboratory is ultimately measured by outcomes that demonstrate it has a contributing value to its Service. These outcomes are:[33]

- S&T focused on war-fighter needs
- Development of revolutionary capabilities
- Efficient technology generation for the resources expended
- Effective technology transition
- High involvement in Service decisions
- High value by the major customers

These outcomes simply cannot be duplicated within the construct of peer-reviewed research at a university.

TRANSFORMING DEFENSE BASIC RESEARCH

While the DoD struggles to transform its own research infrastructure and strategy, the National Institutes of Health (NIH) is attempting to do the same in order to make better utilization of its nearly $13B basic research budget (FY2003). The National Academy of Sciences was recently commissioned by the National Institutes of Health (NIH) to study and make recommendations on changes to their basic research funding strategy.[34] While NIH research is primarily focused on the biomedical sciences, their funding strategy is similar to the DoDs. Like the DoD, the NIH relies on heavily peer-reviewed extra- and intra-mural research to solve problems requiring a discovery system of inquiry. Several of the recommendations made by the NAS study committee could also certainly apply to the Department of Defense.

The most fundamental recommendation, yet the most difficult to implement, is the establishment of a set of metrics to assess the technical and scientific output of each project. Additionally, the National Academies recommend that project assessments should be made periodically by external, independent peer review panels and should include scientist from academia, government, and industry. They further recommend that this evaluation should include an assessment of benefit to "the field."[35] This sounds very similar to the TARA process used by DDR&E in preparing the POM. In reality the TARA itself does not evaluate the research, but establishes an advisory group for each DTO or JWTO to make the necessary evaluations on funded research. Each DoD advisory group provides the necessary expertise to the Under Secretary of Defense (Acquisition, Technology, and Logistics), the Director, Defense Research and Engineering, the Deputy Under Secretary of Defense (Science and Technology), the Director, Defense Advanced Research Projects Agency, and the Military Departments in order to develop a research investment strategy. All research in support of the Department of Defense receives some form of periodic review, generally biannually, from a panel formed by the awarding agency or DoD advisory group. Researchers must also submit annual progress reports on their funded project. These project reviews are then used to prepare the agency and project reviews at the TARA. In both forums the researchers report on the extent of their efforts couched in terms of the published metrics.

This brings us back to the question of which metrics should be used to measure the effectiveness of basic research. The Government Performance and Results Act of 1993 (GPRA) calls for federal agencies to develop, by the end of fiscal year 1997, multi-year strategic plans and metrics for assessing progress toward agency goals.[36] For research funding agencies like the Defense Advanced Research Projects Agency (DARPA) or the Army Research Office (ARO), these metrics include: a list of papers submitted or published during this reporting period, demographic data (number of scientists or students supported), a report of inventions, a description of any significant theoretical or experimental advances, and amount of "technology transfer." In this context, ARO defines technology transfer as "any specific interactions or developments which would constitute technology transfer of the research results. Examples include patents, initiation of a start-up company based on research results, interactions with industry/Army R&D Laboratories or transfer of information which might impact the development of products."[37] The first four metrics are attractive to program mangers and review panels, because they are easy to enumerate and lend themselves well to statistical analysis. While metrics such as these indicate the size and health of a research program, they are essentially irrelevant in regards to meeting the technology needs of the DoD.

The Office of Management and Budget (OMB), under the Clinton and current Bush administrations, has tried to improve the management of basic research programs across the federal government, by reinforcing or adopting best management practices and not on predicting the outcome of worthwhile basic research. OMB has proposed using "Quality, Relevance and Performance" as guideline metrics for measuring the investment criteria for basic research programs. The intent of these initiatives is to bring clearer information on program performance to bear upon future resource allocation decisions. In order to measure the quality of a research program, agencies are required to periodically examine their projects for scientific and technical excellence by benchmarking them relative to other programs, other agencies, and other countries. To demonstrate relevance, research programs, including unsolicited programs, must identify and prioritize individual research goals and demonstrate the linkages back to National initiatives or overall relevant research goals. A program's performance is then evaluated by setting and meeting a series of high priority, multi-year research objectives.[38] It is therefore essential that the DoD require all research programs to establish clear, but flexible plans with well-defined milestones that are linked to specific DTOs or JWTOs.

The U.S. Army has recently taken a different approach to managing extramural research from the approaches discussed above. One of the Army's main efforts has been to attract the best and brightest to work solving the Army's problems through the establishment of University Affiliated Research Centers (UARCs) and Collaborative Technology Alliances (CTAs). There are currently four DoD approved centers and five CTAs that are collaborative partnerships between academia, government and industry. These centers hope to combine the ability of universities to produce cutting-edge research, the expertise of industry to manufacture technology, and the knowledge of government scientist to guide the research efforts in a manner that meets the needs of the war-fighter.[39] The UARCs encompass the areas of Nanotechnology, Advanced Simulations, Biotechnology, and Electrodynamics ; while the CTAs encompass the areas of Advanced Sensors, Power & Energy, Advanced Decision Architectures, Communications & Networks, and Robotics. The financial commitment from the government for each UARC is $50 million over five years and for each CTA is approximately $35 million over five years. Each of these programs use some form of a Research Management Board (RMB) with participation from other Army organizations, other Services and other government agencies. While the CTAs are managed by a senior ARL representative designated as the Collaborative Alliance Manager (CAM), the UARCs are managed by the university. As an exception the Institute for Soldier Nanotechnology, established at the Massachusetts Institute of Technology (MIT) in 2003, does have an Army Acquisition Corps liaison officer and several ARL researchers on campus. While the Army is leveraging the facilities and resources of academia and industry to support its own internal research efforts, these programs are too recent to determine their impact on future war-fighting technologies.

CONCLUSIONS

In 1945 Vannevar Bush established a vision of publicly funded research in which he urged the scientists mobilized to fight World War II to turn their efforts towards solving “the needs and desires of man” once the fighting had ceased.[40] As a result of implementing the Bush vision, research universities within the United States have become the envy of the world mostly using public funding and they have done so at the expense of funding for our Service laboratories.

However Dr. Bush clearly recognized the continued need for focused research to support national security. With a basic research budget less than half that of the National Science Foundation and a mere fraction that of the NIH, the DoD cannot afford to pursue lofty science education goals and satisfy the DTOs and JWTOs necessary to meet the needs of future war-fighting. Additionally, no single approach to funding basic research will be able to satisfy the tremendous technology needs of the future force. A combination of closely managed extramural and intramural research efforts are needed to solve the immense technological challenges of the future. Setting broad priorities for basic research is the domain of policymakers in Congress and the Administration, but it should be the result of informed policy debate. The DoD will probably continue to fund public universities in order to maintain a strong scientific research base, but it should recognize that its impact on providing capabilities to the war-fighter is minimal without specific mechanisms to ensure overall quality. [41]

The new approaches of establishing collaborative venues and centers of excellence incorporating elements of the service laboratories, industry, and university researchers are the key to achieving a successful and rapid transition of scientific knowledge into fielded technology. The unique setting of these centers in a university setting allows the scientific field to determine the quality of the research through the peer-review process, freeing the DoD to focus on guiding the scope of the research in pursuit of developing defense specific technologies. In light of OMB initiatives and the Government Performance Results Act of 1993, the DoD should restrict research program metrics to those that are linked to well-defined milestones in support of DTOs or JWTOs. Not only will this allow program managers to monitor or assess the progress of the research, but it will allow for the phasing out of a program once the stated ends are met or eliminating it if the research effort falls short of expectations.

The ability of the DoD to leverage research within the university and industrial base is predicated on using government scientist to shape the basic research into key war-fighting technologies. This assumption is only valid if we have strong DoD laboratories that attract world-class scientists. However our defense laboratories are in a state of severe crisis. An approach worth considering is to eliminate or minimize funding of basic research at universities in order to build world class defense laboratory facilities using the Government-Owned/Contractor-Operated (GOCO) model utilized by both the National Aeronautics and Space Administration (NASA) and the Department of Energy (DoE). Laboratories like Sandia, Los Alamos, Jet Propulsion Laboratory (JPL), and Lawrence Livermore are world renowned for their contributions to the scientific field as well as to their respective agency. In each of these laboratories, the agency has contracted a university to manage the facility and has made them accountable for research goals. Research is conducted by government personnel, university professors and graduate students, and contract personnel. To attract new research ideas, these agencies provide small travel grants for collaborative groups to use the facility with the assistance of permanent staff researchers. The DoD could follow the same approach with its service laboratories by contracting their management to universities or combine them into a Joint Research Laboratory under single university management. Using this model, the DoD could have the best of both worlds by sponsoring research that is accountable to meeting stated Defense Technology Objectives and serves to meet more altruistic goals like encouraging students in scientific disciplines. At any rate it is clear that the Deputy Under Secretary for Defense, Science & Technology needs to take immediate action to reverse the funding and management trends at the Service Laboratories in order to recruit and retain the high quality, dedicated scientists and engineers necessary to conduct and manage cutting-edge research.

WORD COUNT = 5435

ENDNOTES

[1] Quadrennial Defense Review Report, (Washington, DC: Department of Defense, September 30, 2001), 6.

[2] Basic Research Plan, DOD, DDR&E, Washington, DC, February 2003, I-1.

[3] Vannevar Bush. Science the Endless Frontier (40th Anniversary Edition). Washington, DC: National Science Foundation, 1990.

[4] Government Funding of Scientific Research: A Working Paper of the National Science Board. Washington, DC: U.S. Government Printing Office, 1997. (NSB-97-186).

[5] "Global Positioning System (GPS)". http://samadhi.jpl.nasa.gov/msl/Programs/gps.html. Internet. Accessed 12/10/2003.

[6] Defense Science and Technology Strategy, (Washington, DC: Department of Defense, Deputy Under Secretary of Defense, Science and Technology, May 2000), 1.

[7] Defense Science and Technology: Reliance, (Washington, DC: Department of Defense, Deputy Under Secretary of Defense, Science and Technology, March 2001), vi.

[8] Defense Technology Area Plan, (Washington, DC: Department of Defense, Deputy Under Secretary of Defense, Science and Technology, February 2003), ES-4.

[9] Joint War-fighting Science and Technology Plan, (Washington, DC: Department of Defense, Deputy Under Secretary of Defense, Science and Technology, February 2003), I-4.

[10] Industry R&D Coalition Critique of February 2002 DDR&E S&T Plan, Letter from Dick Engwall RLEngwall & Associates Chairman of Industry R&D Coalition, to Robert Baker Deputy Program Director, August 5, 2002. (Available from http://www.dodmantech.com/pubs/pubs.shtml). Internet; accessed 25 January 2004.

[11] Defense Technology Area Plan, (Washington, DC: Department of Defense, Deputy Under Secretary of Defense, Science and Technology, February 2003), ES-2.

[12] Defense Basic Research Plan, (Washington, DC: Department of Defense, Deputy Under Secretary of Defense, Science and Technology, February 2003), III-1.

[13] Ibid., III-4.

[14] Ibid., IV-1.

[15] National Science Foundation. *Survey of Federal Funds for Research and Development: Fiscal Years 2000, 2001, and 2002*. National Science Foundation, Division of Science Resources Statistics. (Available from http://www.nsf.gov/sbe/srs/nsf02321/sectc.htm). Internet; accessed 25 January 2004.

[16] Ibid., III-2.

[17] Dr. Joseph Rocchio, Director, Sensors and Electronic Devices Directorate, U.S. Army Research Laboratory, interview by author, 30 December 2003, Adelphi, MD.

[18] America's Basic Research: Prosperity Through Discovery, Copyright Committee for Economic Development, 1998, New York, NY, 32-47.

[19] National Research Council, Committee on Criteria for Federal Support of Research and Development, Allocating Federal Funds for Science and Technology (Washington, DC: National Academy Press) 1995.

[20] Larry C. Russell, Jr., Ph.D., larry.russelljr@us.army.mil, “Re: MURI Projects: Technology Transition?” Electronic mail message to author. 12/19/2003 1:28 PM.

[21] Office of the Under Secretary of Defense (Acquisition, Technology and Logistics). *Managers Guide to Technology Transition in an Evolutionary Acquisition Environment, Defense Procurement and Acquisition Policy, Version 1.0* , Washington, DC: Office of the Under Secretary of Defense (Acquisition, Technology and Logistics) January 31, 2003, 2-10 – 2-11.

[22] National Research Council, Committee on Criteria for Federal Support of Research and Development.

[23] Department of Defense Congressionally Directed Medical Research Programs. http://cdmrp.army.mil. Internet; accessed 25 January 2004.

[24] Donald Kennedy “Industry and Academia in Transition”, *Science*, Nov 21, 2003, 1293.

[25] Madeleine Jacobs “Whither Long-Term Industry Research?: A shift in support for basic research in industry raises questions about the U.S.'s ability to compete”, *C&EN*, Washington, May 5, 2003, Volume 81, Number 18, 37-39.

[26] Kennedy.

[27] Ibid.

[28] “Science and Technology Workforce for the 21st Century”, Office of the Chief Scientist of the Air Force, Washington, DC. July 1999.

[29] “Science and Technology (S&T) Community In Crisis”, Naval Reserve Advisory Committee, Office Of The Assistant Secretary Of The Navy (Research, Development And Acquisition), Washington, DC, May 2002.

[30] Ibid., 2.

[31] Jacobs.

[32] “Science and Technology (S&T) Community In Crisis”, 1.

[33] Ibid., 18.

[34] “Large-Scale Biomedical Science: Exploring Strategies for Future Research”, Institute of Medicine, National Research Council (Washington, DC: The National Academy Press) 2003.

[35] Ibid., 195.

[36] Government Performance Results Act of 1993. One Hundred Third Congress of the United States of America, 5 January 1993. http://www.whitehouse.gov/omb/mgmt-gpra/gplaw2m.html. Internet; accessed 16 Feb 2004.

[37] U.S. Army Research Laboratory's, Army Research Office, Reporting Instructions, ARO Form 18, July 2003, http://www.arl.army.mil/aro/forms/arofm18/form18_2004.pdf. Internet; accessed 9 Feb 2004.

[38] Evaluating Federal Research Programs, Research and the Government Performance and Results Act, Committee on Science, Engineering, and Public Policy, National Academy of Sciences, (National Academy Press: Washington, D.C.),1999.

[39] John A. Parmentola, "University Affiliated Research Centers", *Army AL&T*, Fort Belvoir, VA, November – December 2003, 30 - 32.

[40] Vannevar Bush, "As We May Think", *The Atlantic Monthly*, July 1945, Volume 176, No. 1, 101-108.

[41] America's Basic Research: Prosperity Through Discovery, Committee for Economic Development, 1998, New York, NY, 32-47.

BIBLIOGRAPHY

Bush, Vannevar. “As We May Think”, *The Atlantic Monthly*, July 1945, Volume 176, No. 1, 101-108.

Bush, Vannevar. *Science the Endless Frontier (40th Anniversary Edition)*. Washington, DC: National Science Foundation, 1990.

Committee for Economic Development. *America's Basic Research: Prosperity Through Discovery*, Committee for Economic Development, 1998, New York, NY. 32-47.

Committee for Economic Development. *America's Basic Research: Prosperity Through Discovery*, Committee for Economic Development, 1998, New York, NY.

Committee on Science, Engineering, and Public Policy. *Evaluating Federal Research Programs, Research and the Government Performance and Results Act*. Committee on Science, Engineering, and Public Policy, National Academy of Sciences, Washington, D.C.: National Academy Press, 1999.

Department of Defense. *Defense Basic Research Plan*. Washington, DC: Department of Defense, Deputy Under Secretary of Defense, Science and Technology, February 2003.

Department of Defense. *Defense Science and Technology Strategy*. Washington, DC: Department of Defense, Deputy Under Secretary of Defense, Science and Technology, May 2000.

Department of Defense. *Defense Technology Area Plan*. Washington, DC: Department of Defense, Deputy Under Secretary of Defense, Science and Technology, February 2003.

Department of Defense. *Defense Technology Area Plan.* Washington, DC: Department of Defense, Deputy Under Secretary of Defense, Science and Technology, February 2003.

Department of Defense. *Joint War-fighting Science and Technology Plan*. Washington, DC: Department of Defense, Deputy Under Secretary of Defense, Science and Technology, February 2003.

Department of Defense. *Basic Research Plan*. Washington, DC: Department of Defense, DDR&E, February 2003.

Department of Defense. *Congressionally Directed Medical Research Programs.* http://cdmrp.army.mil. Internet. Accessed 1/25/2004.

Department of Defense. *Defense Science and Technology: Reliance*. Washington, DC: Department of Defense, Deputy Under Secretary of Defense, Science and Technology, March 2001.

Department of Defense. *Quadrennial Defense Review Report*. Washington, DC: Department of Defense, September 30, 2001.

“Global Positioning System (GPS)”. http://samadhi.jpl.nasa.gov/msl/Programs/gps.html. Internet. Accessed 12/10/2003.

Government Performance Results Act of 1993. One Hundred Third Congress of the United States of America, 5 January 1993. http://www.whitehouse.gov/omb/mgmt-gpra/gplaw2m.html. Internet. Accessed 16 Feb 2004.

Industry R&D Coalition. *Critique of February 2002 DDR&E S&T Plan, Letter from Dick Engwall RLEngwall & Associates Chairman of Industry R&D Coalition, to Robert Baker Deputy Program Director*, August 5, 2002. (Available from http://www.dodmantech.com/pubs/pubs.shtml). Internet. Accessed 25 January 2004.

Institute of Medicine. *Large-Scale Biomedical Science: Exploring Strategies for Future Research*, Institute of Medicine, National Research Council, Washington, DC: The National Academy Press, 2003.

Jacobs, Madeleine. "Whither Long-Term Industry Research?: A shift in support for basic research in industry raises questions about the U.S.'s ability to compete", *C&EN*, May 5, 2003, Volume 81, Number 18, 37-39.

Kennedy, Donald. "Industry and Academia in Transition." *Science*, Nov 21, 2003, 1293.

National Research Council, Committee on Criteria for Federal Support of Research and Development. *Allocating Federal Funds for Science and Technology*. Washington, DC: National Academy Press, 1995.

National Science Foundation. *Survey of Federal Funds for Research and Development: Fiscal Years 2000, 2001, and 2002*. National Science Foundation, Division of Science Resources Statistics. (Available from http://www.nsf.gov/sbe/srs/nsf02321/sectc.htm). Internet. Accessed 25 January 2004.

Naval Reserve Advisory Committee. "Science and Technology (S&T) Community In Crisis," Naval Reserve Advisory Committee, Office Of The Assistant Secretary Of The Navy (Research, Development And Acquisition), Washington, DC: May 2002.

Office of the Chief Scientist of the Air Force. "Science and Technology Workforce for the 21st Century", Office of the Chief Scientist of the Air Force, Washington, DC: July 1999.

Office of the Under Secretary of Defense (Acquisition, Technology and Logistics). *Managers Guide to Technology Transition in an Evolutionary Acquisition Environment, Defense Procurement and Acquisition Policy, Version 1.0*, Washington, DC: Office of the Under Secretary of Defense (Acquisition, Technology and Logistics) January 31, 2003.

Parmentola, John A. "University Affiliated Research Centers", *Army AL&T*, Fort Belvoir, VA, November – December 2003, 30 - 32.

Rocchio, Joseph, Director, Sensors and Electronic Devices Directorate, U.S. Army Research Laboratory. Interview by author, 30 December 2003, Adelphi, MD.

Russell, Larry C., larry.russelljr@us.army.mil, "Re: MURI Projects: Technology Transition?" Electronic mail message to author. 12/19/2003 1:28 PM

U.S. Army Research Laboratory's, Army Research Office, Reporting Instructions, ARO Form 18, July 2003, http://www.arl.army.mil/aro/forms/arofm18/form18_2004.pdf. Internet. Accessed 9 Feb 2004.

U.S. Government Printing Office, *Government Funding of Scientific Research: A Working Paper of the National Science Board*. Washington, DC: U.S. Government Printing Office, 1997. (NSB-97-186).