

Army R&D Collaboration And The Role of Globalization In Research

John W. Lyons

**Center for Technology and National Security Policy
National Defense University**

July 2008

Report Documentation Page				Form Approved OMB No. 0704-0188	
Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.					
1. REPORT DATE JUL 2008		2. REPORT TYPE		3. DATES COVERED 00-00-2008 to 00-00-2008	
4. TITLE AND SUBTITLE Army R&D Collaboration and the Role of Globalization in Research				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) National Defense University, Center for Technology and National Security Policy, 300 5th Avenue SW, Washington, DC, 20319				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					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT Same as Report (SAR)	18. NUMBER OF PAGES 19	19a. NAME OF RESPONSIBLE PERSON
a. REPORT unclassified	b. ABSTRACT unclassified	c. THIS PAGE unclassified			

The views expressed in this article are those of the authors and do not reflect the official policy or position of the National Defense University, the Department of Defense or the U.S. Government. All information and sources for this paper were drawn from unclassified materials.

John W. Lyons is Distinguished Research Professor at the Center for Technology and National Security Policy at the National Defense University in Washington D.C. He is the retired director of the Army Research Laboratory. He was previously the director of the National Institute of Standards and Technology. He is also a member of the National Academy of Engineering.

Defense & Technology Papers are published by the National Defense University Center for Technology and National Security Policy, Fort Lesley J. McNair, Washington, DC. CTNSP publications are available at <http://www.ndu.edu/ctnsp/publications.html>.

Contents

Introduction.....	1
Some Approaches	1
Formal Collaboration	3
New Centers of Excellence—UARCs	7
International Collaboration	8
Factors in Considering International Collaborations	10
Recommendations.....	13
Conclusion	15

Introduction

Given that budgets are always constrained and R&D managers are never able to do all the worthwhile projects that are proposed to them, it is important to have some way to think about the relative and absolute value of various R&D investment options. In industry, this is normally done by expressing the return on investment (ROI). The ROI is typically calculated by dividing the cost of the work by the value of the improvement in an existing product, or the value of a new product. In the Army there is no bottom line analogous to net profit; rather, there are improvements in warfighting and related capabilities, improvements that may be hard to evaluate in terms of dollars.

The Army's Office of the Deputy Assistant Secretary for Research and Technology (DAS (RT)) seeks better ways to evaluate proposals for developing new or improved technologies to support the warfighter. Currently, these decisions are usually made in accordance with evaluations of the R&D proposals by groups of experts drawn from the technical community and representatives of the warfighters. (In fact, proposals have likely been through a series of such reviews at the many levels between the bench-level scientist or engineer and the DAS(RT)). Implicit in such evaluations is a subjective judgment by each of the participants of the relative and absolute value to the Army.

The absolute value of the new or improved technology is often considered in terms of increases in lethality, survivability, or both. Other improvements include: improved accuracy or speed in the acquisition cycle, more efficient manufacturing and test and evaluation; in logistic support; in combat casualty care; and so on.

The paper first considers a number of approaches to collaboration in research. In particular, examples of collaboration governed by some form of written agreement or contract are discussed. Following these sections, data are reviewed that show the rising level of competence in research in countries around the world; these data show the potential value of international collaboration for improving the effectiveness of Army S&T. The paper closes with discussion of the challenges inherent in increasing international collaboration in military research and makes recommendations for a way forward.

Some Approaches

The Ministry of Defence in the United Kingdom has recently published a comparative study of the ROI of military research and development by pair-wise comparison of the quality of platforms (tanks, etc.) developed by a number of nations.¹ This comparison provides a measure of the relative efficiency of the investments in technology among the participating nations. It also shows where the optima for investment may lie. In other words, the study presents criteria to decide if one is overinvesting to achieve relatively small improvements, or if there is room for continued investment before encountering diminishing returns. The study relies on the expertise of many different participants, is at best semi-quantitative, and gives no extra credit for large differences in capabilities.

More quantitative methods for estimating the ROI for research and development have been developed, mostly for industrial applications. Little has been done for government investments, and almost none for DOD investments. Indeed, the Project Hindsight study done by the DOD in

¹ Middleton, Bowns et al., "The Effect of Defence R&D on Military Equipment Quality," *Defence and Peace Economics*, Volume 17, No. 2 (April 2006).

the 1960s to look at the impact of previous investments in S&T and the resultant military platforms concluded that it was not possible to determine the ROI for particular S&T programs.² This was because results were shared by different platforms, and there were no algorithms to apportion the investments.

However, a possible new approach is proposed in response to the charge for this study. The methodology and the testing of it in a particular use case or scenario are described in companion papers.³ The ROI on research can also be improved by increased use of expertise elsewhere, by the effectiveness of the personnel, equipment, and facilities provided, and by good management practices.

When considering how to carry out a research project, there are options in managing the S&T that could reduce the investment for a given outcome, or improve the outcome for a given investment. One such possibility is to share the research cost by collaborating with others outside the Army, such that a greater span of expertise is brought to bear (presumably delivering improved capabilities) and cost-sharing so that the Army investment is less.

It is not possible for the Army's in-house laboratories to be leading experts in all the technologies the Army requires. Nor should they be.⁴ Whereas the Army is dominant, for example; in technologies for arms and armaments, helicopters and missiles, the private sector is clearly dominant in building computers, in many aspects of electronics, and in telecommunications. The Army need not duplicate private sector-expertise in such fields. However, the Army does need enough competence to transfer private- sector technology to the Army laboratories for adaptation to specific Army needs.⁵

This paper considers collaborations in R&D as they have been conducted in the Army in the past. It then discusses opportunities for more benefit (greater ROI) offered by the changing landscape in the global research and development community.

There are different degrees of collaboration—some are very close; others are at arms length. Recent studies of the development of four Army systems demonstrated that collaboration and close teamwork between Army in-house laboratories and contractors were essential to success.⁶ These collaborations were mostly with U.S. contractors.

² Office of the Director of Defense Research and Engineering, *Project Hindsight: Final Report* (Washington, DC: Office of the DDRE, 1969).

³ A. Sciarretta, J. Willcox, work in progress at the Center for Technology and National Security Policy, National Defense University, Washington, DC.

⁴ See John Lyons, J.N.Mait, D.R.Schmidt, "A Strategy for Improving Army Research and Development Laboratories" in "Strengthening the Army R&D Program," *Defense and Technology Paper 12* (Washington, DC: Center for Technology and National Security Policy, 2005). The advantages of knowledge specialization are also discussed in: Richard Chait, John Lyons, Duncan Long, Al Sciarretta, *Enhancing Army S&T: Lessons from Project Hindsight Revisited* (Washington, DC: Center for Technology and National Security Policy, 2007). Also see John Lyons, Richard Chait, and Duncan Long, "Critical Technology Events in the Development of Selected Army Weapons Systems, A Summary of Project Hindsight Revisited," *Defense and Technology Paper 35* (Washington, DC: Center for Technology and National Security Policy, 2006).

⁵ The Army does not and should not consider major reductions in or elimination of its in-house laboratories. On the contrary, we have found the role of the in-house laboratories to be essential to the creation and fielding of new Army systems.

⁶ Chait et al., *Enhancing*, chapter 1.

Research collaboration is taken here to mean close day-to-day working relationships between Army scientists and engineers and peers at other laboratories—in other DOD elements, other government agencies, in industry, or in universities. Other forms of work sharing are commonly used by the Army. One form used is the assignment of segments of the work by contracts and grants to others. Contracts and grants usually operate at “arms length”. In a contract the Army specifies what the results are to be, usually in distinct milestones, and then leaves it to the contractor as to how to carry out the work. In a grant, the Army decides, based on a proposal, that the qualifications of the proposer and the merit of the proposal warrant an investment. Ordinary grants do not have milestones and no specified deliverable other than new knowledge; the Army has only the option of whether or not to renew a grant after the fact. Most of this work has been with industry and universities within the United States.

In several CTNSP studies of earlier successful application of technology to Army platforms, there are examples of the Army working through contractors to achieve the end result.⁷ The contractors are assigned engineering of the platform, development of prototypes for test and evaluation, and finally, production. At times the contractors also performed some of the S&T work (Science and Technology, referring here to applied research and advanced development). In only a few cases did the contractors and the Army perform as integrated research teams.

Internationally, the relatively few examples of collaboration in military research have been through work division with other national agencies working on specific subsystems. Often the Army simply acquires a piece of technology from another country, and then adapts it to its own needs. An example is the 120mm gun for the Abrams main battle tank.⁸ The Army decided to install an existing 105mm gun in the early versions of the Abrams tank pending the completion of a German program on a 120mm gun. The Army then acquired the German technology and improved upon certain aspects, especially in manufacturing. Is this collaboration or simply cooperation?

Formal Collaboration

A new form of contracting called *cooperative agreements* (not to be confused with Cooperative Research and Development Agreements (CRDAs)) with outside entities has been created by the Congress.⁹ The authorized use is when “substantial involvement is expected between the executive agency and the State, local government, or other recipient when carrying out the activity contemplated in the agreement.” These statutes closed the gap between contracts and grants on the one hand and in-house research on the other, making it possible to have the best of both approaches.¹⁰

⁷ For a summary, see John Lyons et al., *Critical Technology Events*.

⁸ Richard Chait, John Lyons, and Duncan Long, “Critical Technology Events in the Development of the Abrams Tank: Project Hindsight Revisited,” *Defense and Technology Paper 22* (Washington, DC: Center for Technology and National Security Policy, 2005).

⁹ 10USC2358 and The Federal Technology Transfer Act of 1986 (Public Law 99-502) amended the Stevenson-Wydler Technology Innovation Act of 1980 (Public Law 96-480).

¹⁰ Cooperation in basic scientific research has been common, especially in academia. In high energy physics this is the only way the work can be done, because the facilities for experiments are expensive and often unique. The development of quantum mechanics provides a good historical example of the impact on research of international collaboration. Quantum mechanics was developed in Germany, and scientists from all over the world traveled there to work with Max Planck, Max Born, and Albert Einstein. International visitors and students in Germany spread the knowledge across the globe; for example, Robert Oppenheimer was a student of Max Born.

One of the first uses of cooperative agreements by the Army was the program known as the Federated Laboratory (now the Collaborative Technology Alliances). In the early 1990s, the Army Chief of Staff Gen. Gordon Sullivan launched an effort to “digitize” the force. This was the first step in creating an Army networked together on the battlefield by a system of systems of communications, computers, and sensors of various kinds, along with computerized decision aids. This force was eventually termed the Future Combat System. At the time of General Sullivan’s call, the Army’s corporate laboratory—Army Research Laboratory (ARL)—was not organized to address this challenge. The laboratory’s expertise was focused on individual components and platforms. Management decided it would take too long to build the necessary competence, and further, that the private sector had moved ahead in this field. A way was needed to employ this private sector knowledge, while developing enough internal competence at ARL for it to help adapt the technology to Army engineering components. This approach was a better alternative than the traditional one of simply turning over the problem to the private sector. The argument was that if the ARL was to help the Army be a “smart buyer,” then it had to have enough expertise to advise on proposals from the private sector.

The ARL proposed to establish centers of excellence in the private sector using cooperative agreements, in such a way that Army scientists and engineers could actively collaborate in the planning, management, and actual execution of the work. Cooperative agreements were to be awarded to consortia of companies and universities. Because of the experience of major telecommunications and computer companies in fielding the technology, the Army required that each consortium be led by an industrial firm. The work was to be managed by a committee comprised of senior managers from ARL and from members of the consortium. A manager from ARL was to chair the management committee.

The initial work was in basic research although much of it was very nearly applied or what insiders called “late 6.1 or early 6.2.” The thought was, inter alia, to avoid conflicts over sharing the more proprietary applied knowledge of the consortium members and perhaps to make the issue of rights to intellectual property more tractable. A key part of the concept was a staff rotation requirement, which stipulated that staff from ARL and the consortia would spend significant time working in the others’ laboratory. By moving staff back and forth, ARL and consortia members would keep abreast of the needs of their partners. This rotation was intended not only to increase the breadth of experience of the individuals, but also to speed up the process of technology transfer into the Army.

The proposal for the new program, the Federated Laboratory, was to fund five consortia in various fields for a period of 5 years, renewable for an additional 3 years. The proposed budget was for five million dollars a year for each consortium for a total of \$25 million a year or \$125 million for the first 5 years. In the event, Congress only approved funding for three consortia—in advanced and interactive displays, telecommunications/information distribution, and advanced sensors—and eliminated the 3-year renewal provision.

A summary of an early assessment (after 2 years of operations) is as follows:¹¹

...some problems arose ... administrative problems were mainly concerned with meshing three very different operating systems (government, industry, and academia) ...[and] cultural problems revolved around the very different

¹¹ Edward A. Brown, ARL-SR-57, *Reinventing Government Research and Development* (Adelphi, MD: Army Research Laboratory, 1998).

approaches that industry and academia take towards accomplishing tasks ... this “culture shock” has, for the most part, worn off...

As time went on, the success of the Federated Laboratory concept became evident, and Congress approved an expanded program. Two of the first three consortia were renewed. In 2001 the Army awarded five new consortium cooperative agreements:¹²

- Advanced Decision Architectures
- Advanced Sensors
- Communications and Networks
- Power and Energy, and
- Robotics

Funding is \$7 million per year per consortium—a little higher than before. A 3-year option for each was possible at \$20 million.

The improved program is now known as the Collaborative Technology Alliances. The following statement is from the program announcement for the planned ARL CTA on micro autonomous systems technology:¹³

“Experience has shown that for many emerging technologies, high payoff is achieved through collaboration with a broad science and technology community. The US Army Collaborative Technology Alliances (CTAs), which were designed to encourage collaboration, are proving to be a successful model for collaborative technology development. The MAST CTA continues the ARL concept of an Alliance to facilitate a close relationship between ARL and its partners so that collaborative research can leverage and enhance individual efforts. It is ARL's strong belief that work conducted under the [Micro-Autonomous System Technology (MAST)] CTA cannot be successful either in whole or in part without collaboration. That is, collaboration between the members of the Consortium and the Government Members of the Alliance is integral to the execution of the Fundamental Research Component, especially the crosscutting themes identified in part III. Creation of an environment that is conducive to collaboration is therefore a critical element in establishing the Alliance. This section describes potential means to establish a collaborative environment including outreach activities and an on-line presence wherein scientific ideas can be exchanged efficiently in an open environment among all the partners in the Alliance.”

A new provision allows ARL to spend a modest portion (up to 10 percent) at laboratories that are not members of the CTA. Another new provision authorizes a partial shift from basic research to applied work and work on technology transitions. The new CTAs are authorized to spend funds on specific, ordinary contracts for technology transitions; funds may come from ARL (6.2) or from Program Manager Offices or Army Research, Development and Engineering Centers. The

¹² CTA, *Technology for the Soldier, 2001–2006 Report*, available at <http://www.arl.army.mil/www/DownloadedInternetPages/CurrentPages/CTA/Documents/reports/CTA_Book_2007_Web.pdf>.

¹³ United States Army Research Laboratory (ARL), Micro Autonomous Systems and Technology (MAST), Collaborative Technology Alliance (CTA), final Program Announcement (PA), w911nf-06-r-00061 September 2006. Part V, page V-1. The award has just been made to a consortium led by BAE Systems USA; a press release is available by email request to patricia.fox@us.army.mil.

amount of funding depends on the interest of the sponsors, limited to a given ceiling. This broadened participation by stakeholders is also reflected in the composition of special research management boards. (The Air Force's Research Laboratory has a representative in at least one case.)¹⁴

This new form of collaboration has been successful, as evidenced by the increase in number of consortia and the increased funding of each. One can judge the result in terms of the participants in the winning consortia and in terms of the technical successes of each one.¹⁵

Table 1: A Sampling of Members of Successful CTA Consortia

Industry and Research Institutes	Universities
BAE Systems	MIT
General Dynamics Robotics Systems	Carnegie Mellon
Northrop Grumman	Georgia Tech
Telecordia Technologies	University of Michigan
Honeywell	Johns Hopkins
DuPont	Princeton
Sarnoff Corp.	Rensselaer Polytechnic Institute
SRI International	University of Maryland
Jet Propulsion Laboratory	University of Minnesota
	Howard University
	North Carolina A&T

These institutions are leaders in their several fields and have a broad scope of expertise—precisely what was sought. The qualifications of the individuals assigned and the amount of time they are to provide are important indicators of the success of the new approach. (This also applies to the ARL staff assigned to collaborate.) These factors were a part of the selection process.

Several examples of technical accomplishments indicate the progress made.

Examples of Accomplishments by CTAs

- Built new physiological sensors for the individual soldier
- Demonstration of world's second reported quantum dot, vertical cavity, surface-emitting laser
- Developed new higher electron mobility transistors based on GaN; also strain layer superlattices based on GaSb/InAS
- Developed a system for automatic generation of optimal network hierarchies for a large force immediately on arrival; an Automatic Domain Analyzer transitioned to CERDEC for MOSAIC
- Demonstrated power systems using MEMS technology – improved micro turbines including combustors and magnetic generators – for 10 watt level power for the individual soldier

¹⁴ From a discussion at ARL on March 28, 2008 with: John Miller, ARL Director; David Skatrud, Deputy Director and Director, Army Research Office; and Jay Gowens, Director, ARL Computational and Information Sciences Directorate.

¹⁵ *Technology for the Soldier, 2001–2006 Report.*

- Solid oxide fuel cell technology and process for reforming liquid fuels (diesel, J8)
- Transitioned new robotics technology to FCS and others
- Developed LADAR for detection and ranging in UGVs
- Developed intelligent control allowing UGVs, UAVs, UGS (unmanned ground sensors) to be integrated with a small team of soldiers

These accomplishments are just a small sample of consortia work; they range from basic investigation to new applications. Some support other projects, whereas some are being directly transitioned to ARL's client users.

The CTAs are regularly evaluated by the participants and by panels convened from interested parties unaffiliated with the CTAs. The five CTAs launched in 2001 were reviewed by these external evaluation panels in terms of quality, relevance, and performance. Three out of five received excellent overall ratings, while two were rated acceptable. The results of these evaluations, as well as other factors, led to the exercise of the 3-year extension option for three of the five CTAs. The other two were given only limited extensions. ARL management finds that ideas move from the consortia to the Army more quickly than is the case with more traditional means of contracting. This is in part from the staff rotation mechanism and the daily contacts between the research staff in the consortia and ARL staff. Close interaction is also developed from the annual cycle of planning and reviews managed by ARL.

The CTAs have improved the effectiveness—and hence the ROI—of ARL's research programs, by bringing more expertise to the work. At the same time, they have reduced the cost to government by cost-sharing with the external participants.

New Centers of Excellence—UARCs

After the Federated Laboratory (CTA) program was launched, the Army established three large, multi-year funded centers of excellence. These were directed at Army needs, but did not arise from proposals from individual Army laboratories. Instead, they were set up by the Department of the Army as University Affiliated Research Centers (UARCs). UARCs differ from the CTAs in several respects. The funding vehicle is not a cooperative research agreement; under the rules for the UARCs, they must use standard contracts.¹⁶ This means that the UARCs do not present the same opportunities for close collaboration with in-house laboratories as do the CTAs.

The three new UARCs are: the Institute for Creative Technology (ICT), based at the University of Southern California and opened in 1999; the Institute for Soldier Nanotechnology, based at MIT opened in 2002, and the Institute for Collaborative Biotechnology, which opened in 2003 at the University of California, Santa Barbara. Two of these are consortia with members from industry and academe; one (ICT) has flexible and oft-changing arrangements with Army partners. Links to Army in-house laboratories have been created for all three, but these links are not as formal as those of the CTAs. These institutes are another way to develop useful technology for the Army.

With the success of the CTAs and the rapidly improved competitive position of international research and development, the Army considered the possibility of trying the CTA approach with

¹⁶ The UARCs are very like the federally funded research and development centers (FFRDCs) used initially in World War II. In recent years there has been some contention in regard to the impact of these centers of excellence on competition and in their tying up large portions of the S&T budget for extended periods.

an international partner, namely, the British Ministry of Defence. The following sections discuss this new international collaboration in terms of the effects of globalization of research on Army S&T.

International Collaboration

In recent years, advances in science and technology have enabled more and more nations to compete in the global marketplace. Thomas Friedman ties this increased competition to the end of the Cold War.¹⁷ He asserts that when the Berlin Wall came down, it “tipped the balance of power ... toward those advocating democratic, consensual, free-market oriented governance,” thereby adding to world competition. The proliferation of large, multinational corporations has been accompanied by the movement of manufacturing and R&D overseas, and not just to other industrialized nations. Many functions (and jobs) have moved around the globe based on cost and availability of educated work forces. Service operations once based in the United States can now be conducted from halfway around the world.

Information technologies have produced truly international commercial activities, such as global finance, and global newsgathering and distribution in real time. Information is now instantly available via Internet search engines. The bandwidth of optical fibers means that very large documents, images, and other files can be sent anywhere in the world instantly. Heretofore, such files had to be sent through the mail, thereby delaying work by days. The IT revolution has created a third form of research in addition to theory and experiment; namely, research performed entirely on the computer. Theoreticians and modelers work together across the oceans almost as well as if they are together in the same laboratory. Even experimentalists on separate continents can, in real time, discuss experiments in progress and compare results of their work. Thus, it is now possible to conduct many aspects of research with overseas partners through global networks based on the Internet and wide-band communications. Many scientists and engineers in the private sector take advantage of this technology, collaborating routinely with counterparts in other countries and thereby accessing specialized expertise not readily available at home. These are examples of individual collaborations. In recent years in the private sector more formal institutional collaborations have become common wherein companies team with other companies, companies join with universities, and sometimes government agencies form partnerships with both of the above.

These developments have contributed to a narrowing of the commercial and technological leads that the United States has enjoyed since World War II. A recent study by the National Research Council points to the sources of this change: movement of jobs overseas, the decline in the United States’ production of graduates in science and engineering, the high cost of higher education, continuing issues in the competitive quality of K-12 education, and the negative balance of trade in high technology products.¹⁸ American industry has shifted much of its R&D work to short-term, applied work and away from long-term, fundamental studies. Federal funding for S&T in the physical sciences, mathematics, and engineering has been declining since at least FY1976.¹⁹ The tightening of visa controls since 9/11 has reduced the supply of foreign graduate students and visiting scientists needed to make up for the decline in U.S. citizens enrolled in our academic

¹⁷ Thomas L. Friedman, *The World is Flat* (New York: Farrar, Strauss and Giroux, 2006).

¹⁸ *Rising Above The Gathering Storm*, Committee on Prospering in the Global Economy of the 21st Century, Committee on Science, Engineering, and Public Policy (Washington, DC: The National Academies Press, 2006). Also see an update by Norman Augustine, *Is America Falling Off the Flat Earth?*, (Washington DC: The National Academies Press, 2007).

¹⁹ *Rising Above*, 14–17.

programs in S&T. Actions have also been taken since 9/11 to restrict further the movement of technical information, and especially to label as sensitive many kinds of technical information that were formerly open. Another recent National Research Council report looking at the conflicts between national security concerns and the need for free and open exchanges of the results of basic research, stated:

In the view of the committee, U.S. leadership in science and technology—leadership that has been gained in part through the interchange of ideas within the international community—is central to achieving national security in the economic and defense context of the 21st century.²⁰

Further evidence of the erosion of the U.S. lead in science and technology can be found in figures reported by the National Science Foundation.²¹ U.S. trade in high technology products has shifted from a positive \$30 billion in 2000 to a negative \$37 billion in 2004 out of a total of imports and exports of about \$400 billion. Table two below provides additional indicators of technical erosion, and table three on the following page shows the top twelve nations in numbers of S&E publications in 2005.²²

Table 2: U.S. Scientific Performance, Selected Indicators

Indicator	1983	1990	1992	2003	2005
Percent U.S. patents awarded to foreign entities		35		48	47
Percent S&E publications worldwide by U.S. authors			38	30	28.9
Percent S&E PhD degrees awarded to foreign nationals	27			41	40.2
Percent S&E Post-doctoral positions awarded to foreign nationals	36			58	55

²⁰ *Science and Security in a Post 9/11 World: A Report Based on Regional Discussions Between the Science and Security Communities*, Committee on Science, Technology, and Law, National Research Council (Washington, DC: National Academies Press, 2007), 5, available at <http://www.nap.edu/catalog.php?record_id=12013>.

²¹ National Science Board, *Science and Engineering Indicators 2008* (Arlington, VA: The National Science Foundation, January 2008), available at <<http://www.nsf.gov/statistics/seind08/>>.

²² *Science and Engineering Indicators 2008*, appendix, table 5-34.

Table 3: Number of Science and Engineering Publications by Country

Country	Publications (thousands)
United States	205
United Kingdom	46
Germany	44
China	42
France	30
Italy	25
Spain	18
Republic of Korea	16
Netherlands	14
India	14
Sweden	10
Israel	6

Factors in Considering International Collaborations

What does all this mean for Army research and development? Is it possible to enhance capabilities in military technology by joining the global community in the same way that industry and universities are doing? What are the likely advantages and disadvantages? Would military research programs spanning the globe produce better results, such as a higher rate of return on Army research investment?

Given the “flattening” of the world of science and technology, we expect that potential collaborators will become more numerous. By drawing in more competencies that are more diverse, the Army should receive an increase in the quality of the technical results (and hence a higher return on the Army’s S&T investment). The closeness of relations among the two or more collaborators will also provide a broader understanding of each others’ capabilities and capability gaps. The participation of the nations in the partnership will broaden the scope of each’s understanding of the other. Individual researchers, particularly those who engage in prolonged exchanges with partners, will develop a broader knowledge base and gain more experience. Both sides in the partnership should benefit. (We already see this in simple overseas assignments of individual exchanges of Army scientists and engineers.) Success in the research collaboration should also increase the chances of closer cooperation in downstream development, engineering and manufacturing of the new products. This in turn can lead to more standardization of products and processes among allies.

In an earlier paper, the author described the processes by which scientific and engineering information is gathered and assessed by the community at large, and how the results ought to be conveyed to non-technical, senior leaders.²³ The international aspect of this is carried out by the Department of Defense (DOD), in part, by scouting activities in certain parts of the world. DOD has established overseas R&D liaison offices in Europe, Africa, the Middle East, Southwest Asia, and East Asia. Specifically, the Army maintains regional offices in Ottawa, Santiago, Chile, London, and Tokyo, as well as five additional smaller offices, where assessments are made by a

²³ John W. Lyons, “Assessing and Predicting for Army Science and Technology” in “Strengthening the Army R&D Program,” *Defense and Technology Paper 12* (Washington, DC: Center for Technology and National Security Policy, 2005).

combination of attending meetings, reading journals, and making personal visits to laboratories.²⁴ Other federal agencies do likewise, such as the Department of State, the National Science Foundation, the Department of Energy, and the intelligence agencies. Liaison staff write contact reports identifying promising leads. These are sent to the Army laboratories for evaluation and potential opportunities for use in Army programs. As the rest of the world becomes more technically competitive, these activities will likely have to be expanded to additional nations, such as India and China. A new paper recommends that “the Army engage in collaborative fundamental research with top Chinese academic research scientists.”²⁵

In April 2006, in partnership with the United Kingdom’s Ministry of Defence, the Army established the International Technology Alliance (ITA). The ITA was patterned after the CTAs discussed above. The contract document provides the rationale for this arrangement:

The ITA aims to challenge government, industry, and academia to adopt a new way of working. It seeks to break down barriers, build relationships, develop mutual understanding, and work in partnership to develop technology for the U.S. and UK military.²⁶

The ITA seeks to study the topic of network and information sciences. There are two parallel consortia, one in the UK and one in the United States. Both are led by the IBM Corp. There are 25 partners in the two consortia. A little less than two-thirds of the members are from academe. The members possess impressive expertise in the applicable industry and academic fields.²⁷ According to a press release by the Alliance:

The International Technology Alliance opens a new era of collaborative, multi-disciplinary research which spans multiple universities and industrial research labs in the US and the UK. A number of leading researchers have come together to perform joint research, forming a virtual organization of some of the best minds in both countries.²⁸

Using equal funding from the Army and the MOD, the ITA conducts joint planning and execution, with exchanges of staff. This is the first such Army alliance involving another country; it may be a harbinger of things to come. (One indicator of the Army’s view is the creation of an International Collaboration Award in 2007.²⁹)

There are obstacles to overcome in developing successful collaborations, and these are more difficult when doing international agreements. A key issue in any discussion of international

²⁴ *Army Science and Technology Master Plan, 2007* (Washington, DC: Office of the Deputy Assistant Secretary of the Army for Research and Technology, 2007).

²⁵ William Berry, Cheryl Loeb, “China’s S&T Emergence, A Proposal for U.S. DOD – China Collaboration in Fundamental Research,” *Defense and Technology Paper 47* (Washington, DC: Center for Technology and National Security Policy, 2008).

²⁶ “Other Transaction between the ITA Consortium and the US Army Research Laboratory and the UK Ministry of Defence Concerning Network and Information Sciences,” Agreement No. 4911NF-06-50001, May 12, 2006, 6.

²⁷ “The International Technology Alliance, usukita.org”, Technologynews.com, September 18, 2006, available at <<http://www.technologynewsdaily.com/node/4507>>.

²⁸ “RPI becomes a founding member of the International Technology Alliance”, www.cs.rpi.edu, July 19, 2006. Available at <<http://www.cs.rpi.edu/news/stories/story-07192006.html>>.

²⁹ More information on the award is available at the Army Science Conference website, available at <<http://www.asc2008.com/collaborationaward.htm>>.

collaboration by DOD is whether concerns about U.S. military security outweigh the potential advantages of international collaboration. To enter into military international agreements in technology requires security review and clearance at both the Army and the OSD levels, and can be time-consuming. This is more difficult in collaborations with consortia of private-sector entities because of the broader scope and larger number of participants. Clearance may be somewhat less difficult if the work is in basic research. Since the Reagan Administration, there has been in place a National Security Decision Directive (NSDD) that excludes most basic research from export controls.³⁰ However, this NSDD has not settled the conflict between security and the international character of basic science. For example, such work with China is restricted by law. The National Defense Authorization Act of 2000 specifically bars access to DOD laboratories by China.³¹ Considering that China will shortly have the second highest funded R&D program in the world, second only to the United States, this is a serious problem. The CTAs and the ITA require staff rotation to and from the participating laboratories—one of many reasons why China would be currently be disqualified from entrance into these arrangements.

The long war against terrorism has further intensified security concerns. The difficulty increases as one goes along the acquisition cycle toward deployment of products. In the case of the CTAs, the research has been largely basic, but recent changes have added some applied work. For the ITA there is a separate contract for applied research in which each area of applied work must be separately approved.³² The language reads: “each...effort shall be examined on a case-by-case basis for export control and security concerns as these requirements may vary based on the specific [work] contemplated”. This suggests that executing agreements on applied research will face greater difficulty in gaining approval—especially for countries not considered to be sufficiently close allies.

A collaborative agreement must address intellectual property (IP) rights. Given the large number of participants in the CTAs and the ITA, negotiating these rights can be a real challenge. The Army requires that each consortium address the IP issue and have an agreed upon approach before submitting its proposal. Friedman notes that an additional requirement to operate an international collaborative arrangement is to have available staff experienced in managing such projects.³³ He points out that there is a lag between the availability of a new technology and the development of people skilled at using it on an international level. Collaborations are difficult to put together and manage within one country, let alone with other countries. Gaining agreement on technical projects may not come easily because of different military needs in each participating country. Transition out of S&T to downstream work is almost certainly different in different countries.

³⁰ The Federal policy for secrecy in basic research is spelled out in National Security Decision Directive (NSDD) 189, issued by President Ronald Reagan in 1985. For a summary of events leading up to this directive and events since, see J.C. Crowley, “Science and Secrecy: NSDD 189—Prologue to a New Dialog?,” presentation to the American Association for the Advancement of Science, R&D Colloquium, April 18, 2003, available at <http://aau.edu/research/Crowley_files/frame.html#slide0001.html>.

³¹ “National Defense Authorization Act for Fiscal Year 2000” Public Law 106-65, 106th Congress. For a discussion see William Berry and Cheryl Loeb, “China’s S&T Emergence, A Proposal for U.S. DOD – China Collaboration in Fundamental Research,” *Defense & Technology Paper 47* (Washington, DC: Center for Technology and National Security Policy, 2008).

³² “Other Transaction between the ITA and the ARL... Concerning Technology Transitions Efforts for the Network and Information Sciences International Technology Alliance,” Agreement No. W911NF-06-3-0002, May 2006, Section 1.6.

³³ Friedman, 276ff.

Once in operation, there may well be a need for special systems integration functions as a program moves through the acquisition cycle. This is normally done in the U.S. military by a program management office working alongside the prime contractor. It takes time to develop the special knowledge needed to do this effectively.

Recommendations

1. *The Army should continue to explore opportunities to gain expertise from international laboratories.* Successful collaborations rest on a number of factors. There must be clear benefits—that is, the opportunity for improved performance—to the Army. Similarly the private sector participants must see the collaboration as being in their own interests; for example, the effort might enlarge their own research areas and help them learn more about the Army’s technical needs. Questions of ownership of the rights to inventions must be decided beforehand.

2. *Where the priority is high and the needs great, formal arrangements such as those for the ITA should be sought.* Formal collaborations such as the ITA require a considerable commitment of Army laboratory time, talent, and money. Therefore the need must be great; something the Army must do and cannot do alone. There should be a balance of participants as between industry and academe. It is essential that Army laboratory management is capable of handling additional multi year, multi-participant research programs across the oceans. A judgment must be made on the impact of running a number of these collaborations. The Army laboratory staff should not be overburdened with program management to an extent that inhibits the laboratory’s own in-house bench research. Additional funds may be necessary to offset this effect.

3. *The Army should look for opportunities in countries where R&D is of high quality and growing in size.* Opportunities for collaboration should be looked for first at nations in the top dozen or so in the rankings of publications, patents, number of PhD graduates, etc.³⁴ There will be an additional benefit to the Army in acquiring a window on current research and development in these collaborating countries.

4. *Collaborations should begin with basic research and only move beyond that when experience justifies.* The results of basic research are generally open and are international commodities. For most areas of research there will be minimal security concerns, and hence arrangements for the creation of consortia with Army labs should be straightforward. Moving beyond basic research will be more difficult, and should be approached with care. Programs in applied research and beyond should be limited to nations with whom the Army has existing formal exchange agreements.

5. *The bar on access to DOD laboratories by Chinese researchers should be modified to allow personnel exchanges in basic research.* China has reached, in just a few years, the top five in rankings of various indicators of R&D. It seems likely that China will continue to improve upon its status. There are already bilateral agreements for technical exchanges with China dating back to 1979.³⁵ True collaboration cannot be accomplished as long as DOD bars Chinese scientists and engineers from access to its labs.

Both the DOE and the NSF have liaison offices in China. The USG has encouraged Chinese students to spend time in the United States. In 2004, the United States issued 25,647 student and

³⁴ *Science and Engineering Indicators 2008*, appendices 2-11, 2-22, 4-37, 5-24, and 5-40.

³⁵ Berry and Loeb, 10.

exchange visitor visas to Chinese student and exchange visitors.³⁶ During the latter stages of the Cold War, some Soviet scientists were allowed to work in DOD labs in selected technical areas with suitable security procedures in place. Indeed there were some joint technical programs, such as in magnetohydrodynamics. There would seem to be no reason DOD could not do likewise with the Chinese.

³⁶ Available at <www.state.gov/r/pa/prs/ps/2005/47974.htm>.

Conclusion

Clearly, the Army must be careful in conducting R&D with other nations. For each case, the Army must weigh the potential costs in terms of potential security risks against the likely benefits that could accrue to its scientific work. In the current climate of non-state terrorism, the security concerns are very real, and the burden is on the proponents of international collaboration to show that there is no risk beyond that which exists for any collaboration with the private sector in the United States.

However, we believe that the Army will find that in some instances the advantages outweigh the difficulties. How far and wide these arrangements will spread around the world is not clear. As the competence in science in other countries begins to match that of the United States, we can ill afford to cut ourselves off from such sources of new knowledge. As globalization continues to evolve, international collaborative alliances will become more common, and analysis of the benefit and cost ratios will show that many will be well worth the effort.