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External Collaboration in Army Science and Technology:
The Army's Research Alliances

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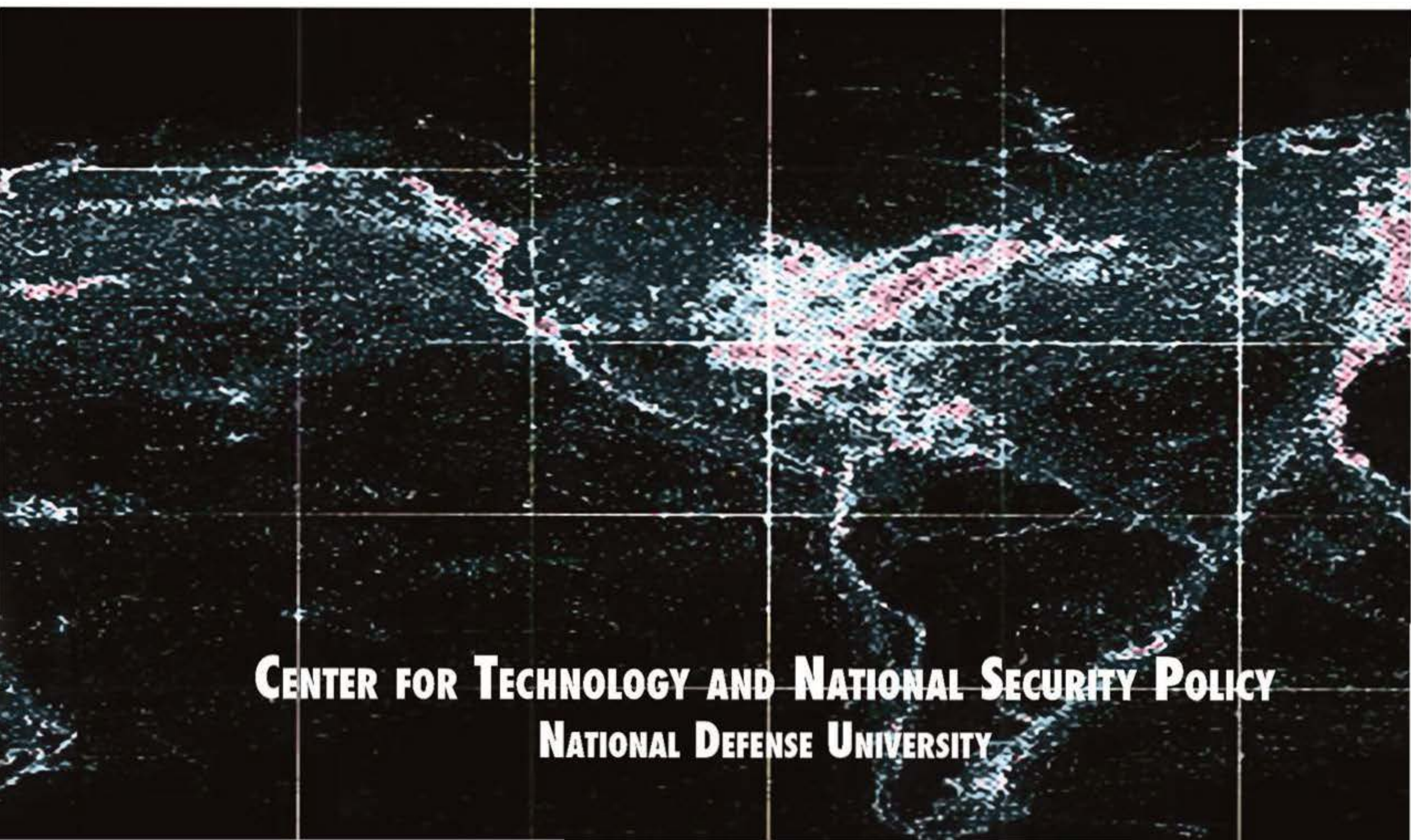

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I. Introduction

No laboratory can be expert in every area important to its sponsor. The laboratory must therefore find other ways to provide the needed talent to complete a project. There are many ways to do this; some formal, some informal.

The U.S. Army gains new technical knowledge through investing in its internal laboratories and in external expertise including single investigator grants and larger, focused centers of excellence. These involve varying degrees of close collaboration with internal Army laboratories. For example, the Army has determined that investing in University Affiliated Research Centers (UARCs) is desirable to obtain new knowledge in areas such as nanotechnology for the soldier and biotechnology. These are large centers consisting of a lead university and a number of associated universities and industries. The information developed is available to Army science and technology (S&T) programs as well as to the general public. These centers are contracted for specific lengths of time and are renewable. Other sizeable investments are in Multidisciplinary University Research Initiatives (MURIs). There are also Federally Funded Research and Development Centers, specific Centers of Excellence, and the Small Business Innovation Research Program, which invests, typically, in small entrepreneurial companies that are able to add to existing internal Army research programs. Most of these programs are executed on contracts that do not specify in any detail how they should collaborate with Army laboratory work.

It should be noted that these programs were not created with the intent to develop collaboration with internal Army laboratories. In this report we focus on more formal modes of collaboration exemplified by the Army Research Laboratory's (ARL) collaborative alliances. We do not attempt to analyze the other forms of investment in external centers of excellence.[1]

Collaborations expose a laboratory to new ideas and new approaches, and subject its programs to critical examination by peers. Collaborations can push the laboratory's investigators to new heights of scientific accomplishment. For this reason, laboratories within the U.S. Department of Defense (DOD) engage in collaboration with the private sector. The Service laboratories offer a unique opportunity to collaborators in the private sector to explore new scientific research they might not otherwise get the chance to engage in. At the individual researcher level, close collaboration between internal laboratory research staff and external investigators is easily done through the Internet and other related technologies to plan and execute a joint project. This is common in most unclassified areas and happens regularly. Use of large groups of external collaborators in the private sector requires some sort of budgetary and legal arrangements.

This analysis will begin with a discussion of how to decide on doing external formal collaborations such as the ARL collaborative alliances. We then consider the ARL Collaborative Technology Alliances (CTAs), Collaborative Research Alliances (CRAs), and the Information Technology Alliance (ITAs). The discussion concludes by looking at whether the current collaborations have been effective, as well as list a set of questions about collaboration that should be answered by Army managers in the future.

[1] For a brief discussion of the other forms of external centers of excellence, see Appendix A.

II. Deciding on Formal Collaboration

Individual collaborations with outside groups occur frequently with little formality, but large-scale and long-term collaboration is a different matter. Whereas individual arrangements do not generally involve a transfer of funds or a contract, the large-scale ones considered here do require detailed justification, budget adjustments, and legal arrangements. Most of the discussion, though based on experiences with the ARL alliances, will also apply to any large external arrangements. The analysis of whether to enter into a formal collaboration involves at least the following seven steps.

1. *List present program priorities for the laboratory.*

The laboratory management should have a clear idea of its own priorities in the current program. This is needed in any case, but for a new effort it may be necessary to refer to the priorities when cutting or eliminating lower priority research programs to free up money, staff, and the like.

2. *List requirements and priorities from the users (warfighters).*

The laboratory managers should have the priority needs of the user clearly in mind to see whether these should be met by the laboratory or by someone else. (Some needs cannot be met by research but rather may require changes in doctrine, logistics, and training, or by purchase in the commercial markets of systems needing no adaptation, for example.)

3. *Assess the capability of the laboratory to meet the new requirements.*

If the problem is technical in nature, then one looks to see if it can be addressed using existing capabilities at the laboratory. For example, if the requirement is in the area of arms and armaments the Army laboratories are well placed to address the problem.

4. *Define the gap(s) in the laboratory's capabilities.*

The laboratory should identify the gaps in its capabilities and look for ways to fill them.

The managers should consider whether they can fill the gap by strengthening the internal programs in a timely manner so as to meet the timelines of the proposed customer, or if going to the external technical community would be more responsive.

5. *Assess the ability of the laboratory to fill the gap(s) from within in a timely fashion.*
   a) Ability to acquire the needed new staff
   b) Ability to secure funding
   c) Ability to acquire the needed equipment and facilities

Filling the gaps internally means that the needed expertise, facilities and equipment are available at the laboratory or can be obtained within the current budget.

6. *If the laboratory cannot fill its gap(s), then an external arrangement is needed.*

The analysis then turns to external collaborations.

7. *A key question regarding external investment is whether the laboratory wants, ultimately to build up its internal expertise?*

If the answer is yes then there must be provision for collaboration in which the internal staff will be in close contact with the outside group(s) working on the problem. If the answer is no, that is, the problem is expected not to require future expertise internally, then investment in arm's length centers may be sufficient.

If the gap(s) are large and a long-term relationship is necessary, some kind of formal contract is required. The nature of the contract depends on the long term intention of the laboratory in the subject field.

In the case of the ARL CTAs, CRAs, and the ITA, the Army needed to develop capabilities, ultimately in the Army's own laboratories, in the fields selected. The Army used cooperative agreements, a relatively new, in the 1990s, contracting tool. Under this tool, the internal managers exercise both oversight and some supervision of the external collaborators. An ARL staff member serves as the Collaborative Alliance Manager.

The following language from the final Program Announcement for the recently awarded

ARL Collaborative Research Alliance for Modeling of Electronic Materials illustrates ARL's intent for the collaboration:

> Collaborations or transition links among the CRAs and the in-house Initiative for Multiscale Multidisciplinary Modeling of Electronic Materials will also be pursued and defined through continuous collaboration, technical exchanges, site visits, staff rotations, and mutual participation in technical reviews during the period of performance.[2]

By means of these mechanisms the in-house researchers stay close to the external members of the consortium, information flows back and forth, technology transfer into the ARL is expedited, and the capability gap is filled.

Alternatively, if the need is not urgent and is likely to persist for a long time, the laboratory could probably create new capabilities through a combination of rearranging internal priorities and hiring new staff, using existing budget. If the need is not urgent and the laboratory sees no opportunity to address it internally, then external grants or contracts can be employed that are not closely tied to the laboratory. Such approaches have been preferred in the past and are still used today. Technical reviews by the sponsor will be at intervals specified in the contract. A final review to determine whether the center is fulfilling the terms of the contract, is conducted at the time of renewal or re-bidding

[2] Program Announcement, *Army Research Laboratory*, undated, 7, available at <www.ARL.Army.mil/www/pages/532/FINAL_MSME_PA.pdf>.

III. Review of the ARL Alliances

Within the U.S. Army, approaches to collaboration include single investigator grants and larger awards to centers of excellence. Grants and contracts are usually not designed to require strong day-to-day interaction with in-house research staff. Rather, the awards are hands-off or arms-length arrangements where the work statement is agreed at the outset and the awardee is independent of the contracting agency until time for renewal. This kind of arrangement supplies new information but is not focused on developing new capabilities of the in-house staff.

In recent years a different kind of contracting authority, the cooperative agreement tool, became available within the DOD and has enabled the creation of collaborative arrangements where the laboratory participates, indeed may control, the work of the contractor on a regular basis. This includes planning and oversight conducted by in-house staff. It also allows for movement of staff back and forth from the laboratory to the contractor. In this way the transfer of expertise from contractor to the laboratory is more effective with resultant broadening and strengthening of the laboratory. The Army has made use of this authority in several instances with considerable success.

In this section, we will review the details of these external arrangements with emphasis on formal collaborations in large, multi-year centers, many as implemented by the Army, and discuss the pros and cons of using this approach. This will be accomplished by reviewing the various collaborative mechanisms used by the Army Research Laboratory, in particular, the CTAs, CRAs and the ITA. CTAs and CRAs are similar in many respects. CRAs are more explicitly focused on basic research; both have provisions for adding funds for applied work. Mechanisms for adding funding vary. The alliances can add either to the existing contract or by establishing separate contracts. These alliances are formal collaborations very closely coupled to Army in-house researchers.

Begun in the 1990s in response to a request from the Army Chief of Staff, ARL was in support of the Communications and Electronics Research, Development, and Engineering Center (CERDEC) in helping to field digital technology to the forces on the battlefield. ARL lacked overall competence in system of systems technology and therefore looked to the private sector for helping with the technology for fielding such products. The idea was to set up formal collaborations in which an industrial firm would form a consortium of industrial and academic members to work in harness with ARL technical staff. This was initially called the Federated Laboratory but was later renamed the Collaborative Technology Alliances. The concept used cooperative agreements, which allowed the ARL to participate, indeed manage, the planning and operational aspects in concert with the alliance leader. Rotation of technical staff was encouraged in both directions. The intent was that the ARL would begin to develop its own expertise and improve the speed and efficacy of the transfer of new results to the Research, Development, and Engineering Center (RDEC), and ultimately to the Program Executive Officers and Program Managers involved in building the systems and fielding them.[3] At first, 3 consortia were funded for 5 years at a budget of approximately $5-6 million a year for each award. Since that time

[3] E.A.Brown, *Reinventing Government Research and Development: A Status Report on Management Initiatives and Reinvention Efforts at the Army Research Laboratory*, ARL-SR-57 (Adelphi, MD: Army Research Laboratory, 1998), 6-13, 6ff.

several projects have been completed and new ones funded. Currently, there are four projects under way: 1) Micro Autonomous Systems and Technology, awarded in 2008; 2) Network Science CTA, awarded in 2009; 3) Robotics CTA, awarded in 2010 and 4) Cognition and Neuroergonomics CTA awarded in 2010. These will be reviewed later in this paper.

The Army recently established two CRAs. The objective of the first CRA, the Materials in Extreme Dynamic Environments, is to establish the capability to design materials for use in specific dynamic environments, especially high strain-rate applications."[4] The objectives of the second, "the Multi-Scale, Multidisciplinary Modeling of Electronic Materials, is to develop quantitative understanding of materials from the smallest to the largest relevant scales to advance the state of the art of electronic, optoelectronic, and electrochemical materials and devices."[4] The Army is preparing to award a third CRA, on cyber security. All three CRAs are too new to be assessed.

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 noted above. The following provides the purpose of the alliance:

"The ITA … seeks to break down barriers, build relationships, develop mutual understanding, and work in partnership to develop technology for the U.S. and UK military. The ITA is studying the topics of network and information sciences." [5]

Regenerative Medicine.
The Army's Medical Research and Materiel Command developed a concept modeled after the CTAs, using the cooperative agreement approach, to establish two consortia to perform research in regeneration of tissues and organs. Advances in adult stem cell research have led to techniques to stimulate the body's mechanisms for recreating damaged tissues and organs. This approach is clearly useful in treating wounded soldiers. The new program is called the Armed Forces Institute of Regenerative Medicine. The first awards were made in 2008 to two groups of medical research teams: one is led by Wake Forest University Baptist Medical Center and the McGowan Institute for Regenerative Medicine in Pittsburgh; a second is led by Rutgers, the State University of New Jersey, and the Cleveland Clinic. These teams work in concert with the Army Institute of Surgical Research at Fort Sam Houston, Texas. The program is funded by contributions from the Army, the Office of Naval Research, the Air Force Surgeon General, the National Institutes of Health, the Veterans Administration, and matching funds from local and private groups. The initial funding from the Government agencies was $42.5 million for five years. Funding from other sources have nearly matched this. We have not studied this effort for this paper.
The Small Business Innovative Research (SBIR) awards provide opportunities for collaboration between the recipient of the award and the group at the DOD laboratory that added the topic to the lists in the SBIR solicitation for proposals. The awardees know who asked for the work and usually seek out the Army staff whose area is involved. These awards initially cover a small portion of the Army project and are narrowly focused. It is often the case that the Army individual will assign part of an ongoing project to the SBIR company. Frequent contact and information flow occurs between the two entities, an arrangement that provides real opportunities for collaboration although not required in the contract.

[4] "Collaborative Research Alliance," *Army Research Laboratory*, undated, available at <www.arl.army.mil/www/default.cfm?page=532.

[5] Networks and Information Science International Technology Alliance (ITA), *Army Research Laboratory*, undated, available at <www.arl.army.mil/www/default.cfm?page=77>; also John W. Lyons, *Army R&D Collaboration and the Role of Globalization in Research*, Defense & Technology Paper 51 (Washington, DC: Center for Technology and National Security Policy, July 2008), 11, ff.

IV. Discussion of the CTAs, and the ITA

Close collaboration with the private sector in research began at the ARL with the Federated Laboratory (Fed Lab) in 1996. Three five-year awards were made: Advanced Sensors, Telecommunications/Information Distribution, and Advanced Displays and Interactive Displays. These contracts contained key provisions that have continued in the later versions termed CTAs, CRAs, and the ITAs. However they have differed in some respects as ARL has learned from each round of awards. CRAs are too new to be assessed at this time.

- The first round (Fed Lab) was funded entirely from basic research 6.1 funds. Later contracts (the CTAs, CRAs, and the ITA) provided for transition using 6.2 applied research funds. However to obtain these 6.2 funds a separate contract competition is usually required. There were no options to extend the awards available in the Fed Lab round. Since then, options of from 3 to 5 years are now available.
- Recent awards have contained provisions for adding new members to the consortia as well as adding other Federal laboratories to join ARL in participating in the collaboration.
- With the funding of the ITA the program became international.
- To ensure collaboration across disciplines, ARL, in 2008, devised a two-stage competition: initial proposals, separately, from each of the major disciplines followed by consolidation of the winners into the final consortium.
- In the Network Science CTA, an experimentation facility is available to all members to test new concepts.
- Rotation of staff from ARL to consortium and vice versa, originally intended to be 20 percent of staff on each side has been made more flexible but with fewer rotations.
- We received several comments to the effect that the collaborators are putting their top people in the consortia and this greatly enhances ARL's effectiveness.

The CTAs

There is general agreement that the CTA approach has been effective in helping the Army fill gaps in its technology. All interviewees[6] expressed satisfaction that the consortium members have been assigning top people and that this has been a plus for the Army science and technology program. There is some concern that the investment of large sums of money in a few large efforts in the private sector has diluted or even reduced the Army's ability to scan a large variety of technical areas through single investigator grants. The single investigator grants are spread out over the technical horizon and provide some assurance that the Army is not missing any future possibilities. The CTAs and the other investments in large external centers have the opposite effect in that they drill down deeply into a few focused areas. Our judgment is that the Army is benefiting from both approaches; the management issue is one of balancing the investments.

As one might expect, the assessment of the individual awards varies across the CTAs and the ITA. (It is too soon to assess the CRAs.) There are differences in the contracting approach and in

[6] A list of individuals who made helpful contributions to this study is at Appendix A.

the manner in which more applied research is supported. We will point out some of these as we go along.

The first awards did not carry options for renewal beyond the first five years and so there was a new overall competition in 2001.[7] This second competition produced five new consortia each with a possible option to extend by three years. Of the five awards, three were extended for the three years; the other two were discontinued after the first five years.

Staff rotation has never neared the original stated goal of having, at any one time, some 20 percent of the staff on both sides in rotation to the other side; that is, the ARL people working the area of the CTA spending time at the consortium, and the consortium sending staff to the ARL. It turned out to be too difficult to uproot this many of the key staff working on the subject matter. But there has been some significant rotation that the managers believe has been helpful.

Micro Autonomous Systems and Technology Alliance (MAST)

The objective of the MAST is to "perform enabling research and transition technology that will enhance warfighter's tactical situation awareness in urban and complex terrain by enabling the autonomous operation of a collaborative ensemble of multifunctional, mobile microsystems."[8] The MAST was competed differently than the early alliances. There are four major areas of technology in the MAST. Each of the areas was competed separately and the winners were then consolidated into a single alliance. This concept was first used in the ITA and was designed to ensure that each of the major areas within the resulting alliance would be properly emphasized. Interactions back and forth have been good. ARL has attracted new staff as a result of the MAST program. The MAST has a separate contract for applied research but no 6.2 funds were provided. It is essentially an authorization for spending 6.2 if someone outside (including ARL) wants to invest their 6.2 funds. Both the Defense Threat Reduction Agency and U.S. Special Operations Command are investing in the MAST. The U.S. Army Corps of Engineers and the U.S. Navy are using 6.2 funds to transition MAST results into their programs.

Evidence of useful collaborations and impacts on the internal ARL program are many. MAST has hired several PhD students from MAST participants and one post doc trained under MAST. There is now a new ARL program funded at $1.5 million dollars in MAST-related mission research. So far there have over 500 publications from the MAST of which several have been jointly written with ARL staff members.[9]

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[7] The facts presented are taken from a presentation by ARL's Dr. Jay Gowens to the National Research Council's Board on Army Science and Technology on May 11, 2010, titled "Rationale and benefits of Various Collaborative Technology Alliance Models."

[8] "Collaborative Alliances," *U.S. Army Research Laboratory*, homepage, undated, available at <www.arl.army.mil/www/default.cfm?page=510>; also see *Micro Autonomous Systems and Technology Alliance* (MAST), homepage, available at <www.mast-cta.org/>.

[9] Brett Piekarski, ARL, email on August 17, 2013.

Sciences Alliance

This CTA was awarded in 2009 for five years with an option for renewal of another five years. The purpose is to:

> Bring together government, industry, and academic institutions to perform foundational, cross-cutting research for a fundamental understanding of interactions, interdependencies, and common underlying science among social/cognitive, information, and communications networks. Prediction and control of the composite behavior of this complex, interacting networks will ultimately enhance effectiveness in network-enabled warfare and counterinsurgency.[10]

There are many kinds of networks ranging from biological to electrical grids. In this CTA the Army is studying three networks that are important in conducting military operations and is attempting to understand the interplay among them will lead to better management of military systems.

The CTA is funded under its cooperative research agreement with both 6.1 and 6.2 dollars. In addition there is a task order contract used to transition results from the CTA to Army user clientele. This vehicle has been used by CERDEC, the U.S. Marines, and the Office of Naval Research. There is an experimentation facility in Cambridge, Massachusetts operated by BBN Technologies, a subsidiary of Raytheon, as a place for working with new results from the consortium. Staff rotation from the consortium, from ARL, and from CERDEC to this center provides good opportunities for collaboration. Similarly, BBN Technologies, a consortium member, is contributing technology that is relevant to this facility and to some ARL studies. And collaboration within the consortium has been increasing with the passage of time, as have interactions with ARL, but to a lesser extent. The effort has led to the establishment of two new journals on network science: *Network Science*, published through Cambridge University Press; and the IEEE *Journal on Selected Areas in Communications* (J-SAC), Special Issues on Network Science.

As an example of collaboration and transition, a report of the predecessor alliance (the Communications and Networks Alliance) discusses work by the Alliance and ARL that developed the techniques, metrics, and tools for survivable, and secure tactical wireless networks on the battlefield. This transitioned to the Communications and Electronics Research, Development, and Engineering Center and thence to the program manager for WIN-T (Warfighter Information Network – Tactical).[11]

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[10] See “Collaborative Alliances” *U.S. Army Research Laboratory*, home page, undated, available at www.arl.army.mil/default.cfm?page=510.

[11] Gregory Cirincione, ARL, email on August 6, 2013.

Robotics

The objective of this CTA is to, "enable the creation of future highly autonomous unmanned systems and permit these systems to effectively conduct military operations in mixed environments."[12] This is the second CTA titled "Robotics." The first was awarded for eight years (five years plus an option for three more). The second began in 2010. The robotics program at ARL had originally been funded from the Office of the Secretary of Defense Joint Robotics Program with funds for advanced technology development or 6.3 category dollars. That effort was devolved to the Army and funding to ARL became applied research funds (6.2) with the U.S. Army Tank Automotive Research, Development, and Engineering Center (TARDEC) assuming the transition role with 6.3 funds. The Office of the Assistant Secretary of the Army for Acquisitions, Logistics and Technology added some 6.1 funding to the ARL in-house program later. The second Robotics CTA has $4.5M in 6.1 funds and $6.5M in 6.2 funds. The CTA differs from the others in the presence of so much 6.2 money and the built-in transition point at TARDEC.

It appears that the restructuring the research in robotics has produced a more balanced program in terms of funding, and defined responsibilities. The CTA has brought needed expertise to the internal program.

Cognition and Neuroergonomics

This CTA was awarded in 2010 with the following purpose:

> The Alliance is expected to implement computational modeling and to execute and link neuroscience based research from multiple levels to produce advances in fundamental science and technology, demonstrate and transition technology, and develop research demonstrators for Warfighter experimentation.[13]

There are six members of the consortium of which two are from overseas; one at Taiwan and one in Germany. The consortium is funded with 6.1 dollars, and has an authorization for 6.2 funding, but so far no funds for 6.2 have been appropriated. The latter provision is similar to that in the MAST CTA. The work involves mapping the brains of many test subjects over lengthy periods followed by digesting the very large amount of collected data. The analysis is done by means of models and the computing power of the computer center at the Aberdeen Proving Ground. The results should help the Army select soldiers with particular aptitudes for certain operational assignments.

Collaboration with the ARL in-house program[14] is evidenced by the fact that a substantial fraction of the ARL papers in peer-reviewed journals have been authored jointly with partners in the CTA. Joint efforts have produced a number of conferences and technical reports. Transitions

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[12] See "Collaborative Alliances," *U.S. Army Research Laboratory*, undated, available at <www.arl.army.mil/www/default.cfm?page=510?>.

[13] See "Collaborative Alliances," *U.S. Army Research Laboratory*, undated, available at <www.arl.army.mil/www/default.cfm?page=510?>.

[14] Kelvin Oie, ARL, email on August 8, 2013.

have been made to the Army Medical Research and Materiel Command and to the Army Tank and Automotive Research, Development, and Engineering Center. Transitions are planned for the Natick Soldier Research, Development, and Engineering Center. These last named transitions were planned under formal agreements between the ARL and the RDECs. The technology developed includes improved methods of measuring brain activity especially wireless techniques that enable measurements outside the laboratory. The work has produced new tools for handling data from studies of the brain. These are being incorporated in the MATLAB™ computing environment, EEGLAB. The development and support of EEGLAB is done by the CTA members.

The International Technology Alliance (ITA)

The purpose of the ITA is as given on the ARL website:

> The Network and Information Sciences International Technology Alliance is a bilateral cooperative technology agreement between ARL and the United Kingdom's Ministry of Defence. The ITA brings together government, industry, and academia to address the fundamental science underpinning the complex network issues that are vital to future coalition military operations and engage the partners in a collaborative environment to fully exploit the joint development of emerging technologies.[15]

The relationships generated among the UK and US participants[16] are critical to the success of the ITA. Compared to previous CTAs, the ITA was a significant step forward in collaborative research efforts by applying an integrated and multidisciplinary management approach. The ITA has transition contracts, one each in the UK and US. These were greatly aided by the ITA lead, IBM, which was the consortium lead in both countries. The British brought a strong focus to the effort and made valiant efforts to protect the continuance of the ITA in the UK. The relative funding size of the ITA in the UK to the UK's military science and technology budget was significantly greater than the proportion of the U.S.'s contribution compared to the U.S. budget.[17]

With respect to the sharing of technology, the International Traffic on Arms Regulations had to be overcome to enable the sharing of new US technology. Some effort was required to handle this restriction. The upshot for the ITA was that sharing technical information from basic research is authorized, so most of the findings can be sent back and forth. But applied technology has to be processed on a case-by-case basis.

As a result of the ITA success in competing the components of the work separately and then joining the pieces in the ITA, ensuing competitions for some new CTAs were handled in this manner.

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[15] "Networks and Information Science International Technology Alliance (ITA)," U.S. *Army Research Laboratory*, undated, available at <www.arl.army.mil/www/default.cfm?page=77>.

[16] The stimulus for this bilateral arrangement originated in correspondence between President George H.W. Bush and U.K. Prime Minister Margaret Thatcher.

[17] John Eicke, email on April 16, 2013.

Some results of the ITA are being transitioned to the North Atlantic Treaty Organization's Intelligence Fusion Center in the United Kingdom. The technology will establish the policy for distribution of fused data from across sectors.

The global application of databases will be facilitated by use of an IBM construct (a Gaian data base) which will permit handling of disparate data bases. Gaian is an IBM product based on how biological systems self-organize. This approach was introduced in the ITA as a means of handling many different modes on a network producing information that needs to be integrated to answer specific questions. Another innovation associated with the ITA is a "boot camp", a management technique for bringing people together for an extended time, for example at a university dormitory to do some formal planning. The process evolved into simply promoting interpersonal relationships and stimulating cross-technology discussions.

V. Findings and Concluding Remarks

Most of the CTAs appear to be successful. Questions that were asked of the interviewees included the degree of collaboration among the members of a consortium and between the consortium and the ARL, the extent to which ARL staff were expanding their expertise as a result of their exposure to the staffs at the consortium, the various ways in which the competition was carried out, and evidence of successful transitions from the consortiums to ARL or to other groups. Based on these questions we found that almost all the CTAs have been successful. One or two of the early ones were not renewed or recompeted at the end of five years. The more recent CTAs and the ITA are considered by those involved in their management to be very successful and have been extended. Positive aspects include the presence of top-flight people in the consortia and improved approaches to multidisciplinary work both at the consortiums and at ARL. The stepwise competition used in competing some of the CTAs and the ITA is intended to ensure a reasonable balance among the several disciplines in the final consortium. However not all the staff associated with CTAs agree with this approach; the use of stepwise competition has not been universal. With the advent of the ITA, international expertise has been added. It is too early to comment on the CRAs.

There has been no independent external evaluation of the Army's research investment in the CTAs and the ITA. The assessment of ARL by the National Research Council's Technology Assessment Board does not include CTAs. We recommend that a more careful, in depth, review of Army Research and Development collaborations be conducted with focus on quality of the work and the extent to which the intentions for the collaborations have been realized. The review should be done by a combination of external experts and in-house senior staff not associated with a CTA.

There are some questions of balance. There have been three different CTAs on robotics and three on network science (the Communications and Network CTA, the ITA, and the Network Science CTA). An issue is whether or not the emphasis on robotics and network science affects other ARL program areas in terms of competing for budget dollars and other resources. The focus of 6.1 funds on these consortia has an effect on the amount of other basic research that can be done at ARL (or single investigator awards at Army Research Office). It is not clear how to balance these alternative means of doing research. It does mean that these areas will have a much broader base of fundamental knowledge than some of the other ARL programs.

In some areas the role of ARL may be questioned. For example, in the area of cyber security the U.S. Government is spending vast sums of money trying to keep up with or ahead of hackers. It is important in such a case that ARL clearly define a niche that is otherwise not being addressed.

The magnitude of staff rotation between the allied laboratories has not been as significant as originally contemplated. The original guidelines of 20 percent of staff be in rotation every year was clearly too much. More recent cooperative agreements have dropped the quantitative requirement but nonetheless emphasized the importance of rotations. There have been a number of rotations for varying lengths of time. In the past there had been some concern at the Office of the Secretary of Defense about the use of 6.1 funds for the CTAs. Discussions with the interviewees indicated that these concerns have no longer been raised at the DOD level.

There is a difference of opinion over how close the relationship is between other modes of collaboration and the in-house laboratories

Transitions from CTAs and ITA have not been quantified in this study; however, because most of the funding to the collaborators is 6.1, more 6.2 applied research will usually be necessary at ARL before the results can be sent along to the RDECs or to the program executive officers and managers. Participation by the potential customers in the management of the collaborations would ensure smoother transitions. This question could be examined in the course of management or peer reviews. We believe the questions listed below, uncovered during discussions with participants are worthy of further study by Army managers:

1. Reviews of progress by external subject matter experts. The National Research Council that reviews ARL's in-house programs does not explicitly review the CTAs etc. Should this be addressed and, if so, how?
2. Source of funding. Some interviewees think that more 6.2 funding (vice 6.1) would be more accurate for at least some of the CTAs. The CTA charters are clearly aimed at addressing specific challenges for the Army. (Close adherence to DOD policy on 6.1 research would suggest that 6.2 funding would be more appropriate for at some of the work in the CTAs.[18])
3. How many and how effective have been the transitions from the consortia to either internal ARL programs or to RDECs and program executive officers and managers.
4. To what extent have the consortia exhibited truly multidisciplinary work?
5. To what extent has the experience with the external collaborators resulted in improved collaboration across directorates within ARL?
6. What is the publication record of the collaborations; is authorship often shared between in-house ARL staff and members of the external consortia? Patents?
7. What is the uniformity of staff rotation across all collaborations?
8. What has been the impact of the collaborations on hiring at ARL?
9. To what extent do the International Trafficking on Army Regulations provisions constrain the work being done in the UK portion of the ITA and the interactions between the U.S. and the UK segments of the ITA?

The trend in research is to utilize the strengths of many laboratories through collaboration rather than one laboratory trying to be expert in every area. Collaborations may be small, with one or two people from each component working together, to large collaborations including multiple entities, substantial funding, and formal contracts. Collaboration is an efficient way to fill gaps in the internal capabilities of a laboratory. Some large scale collaborations such as the CTAs, CRAs, and the ITA at ARL have as the long-term intent, the gradual buildup of internal capabilities. In this case the cooperative agreement mechanism is applicable. We conclude that the collaborative alliances used by ARL as CTAs, CRAs, and the ITA under terms of cooperative research agreements are effective ways to promote close interactions between Army researchers and the technical staffs of the members of the external consortiums. We also believe that the details of the cooperative agreements have improved the internal collaborations within

[18] The DOD policy on the use of 6.1 funding limits such use to basic work not addressing specific problems. See *Assessment of the Department of Defense Basic Research,* Committee on DOD Basic Research, Division of Engineering and Physical Sciences (Washington, DC: National Research Council, 2005).

the consortiums as well as enhancing the expertise of the ARL staff. We have listed a few questions about the ARL alliances the answers to which would further strengthen this approach to external collaboration.

Finally, we suggest that consideration be given to more collaboration between the UARCs, the MURIs, and the like, with internal Army laboratories using the approaches of the cooperative agreement contract detailed here.

Appendix A - Some Other Army Investments in External Centers of Excellence

UARCs

Contracts awarded to universities usually consist of a major research university that shares the work with others in academia or industry. The Army has five of these:

- The Institute for Collaborative Biotechnology (ICB) at the University of California Santa Barbara.
- Institute for Creative Technologies (ICT) at the University of Southern California.
- Georgia Tech Research Institute (GTRI) at the Georgia Institute of Technology.
- The Institute for Soldier Nanotechnologies (ISN) at the Massachusetts Institute of Technology (MIT).
- Institute for Advanced Technology (IAT) at the University of Texas, Austin.

The ICB, first funded in 2003, works with a consortium of leading universities and companies to "transform biological inspiration into technological innovation… biomolecular sensors, bio-inspired materials and energy, bio-inspired network science, and cognitive neuroscience."[19]

The ICT, first funded in 1999, was first established "with a multi-year contract from the U.S. Army to explore a powerful question: What would happen if leading technologists in artificial intelligence, graphics, and immersion joined forces with the creative talents of Hollywood and the game industry?"[20] This was an outgrowth of the Army program to digitize the force and to be more active in adopting the technologies of the information age.

GTRI has a broad base of technologies supported by many sponsors, which the Army is one. This UARC differs from the others in that the Army is not the dominant player. ARL supports work at GTRI on MAST.

The mission of the ISN at MIT, first funded in 2002, "is to help the Army dramatically improve the protection and survivability of the Soldier by working at and extending the frontiers of nanotechnology through fundamental research and transitioning with our Army and industry partners by combining high-tech protection and survivability capabilities with low weight and increased comfort. This Mission includes not only decreasing the weight that Soldiers carry but also improving blast and ballistic protection, creating new methods of detecting and detoxifying chemical and biological analytes, providing physiological monitoring and automated medical intervention, and enhancing situational awareness."[21]

The work of the IAT at the University of Texas has focused on electric or rail guns. The work was sponsored for many years by the Army but recently the U.S. Navy has picked up the technical results and has developed the gun application for shipboard use. Presently the IAT has "… a unique team of world-class scientists and engineers in electrodynamics, pulsed power, and

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[19] *The Institute for Collaborative Biotechnologies*, homepage, available at <www.icb.ucsb.edu>.
[20] *The Institute for Creative Technologies*, homepage, available at <http://ict.usc.edu>.
[21] "About ISN," *The Institute for Soldier Nanotechnologies*, homepage, available at <www.mit.edu/isn/aboutisn/index.htm>.

hypervelocity physics, whose focus has been to develop the fundamental scientific basis for new classes of high velocity kinetic energy weapon systems."[22]

MURIs

These initiatives are consortia of universities doing basic research reaching across disciplinary lines. They are typically funded for five years in response to calls from proposals by three U.S. Department of Defense (DOD) agencies: the Army Research Office, the Office of Naval Research, and the Air Force Office of Scientific Research. In 2011, DOD announced awards to 27 consortia chosen from 113 proposals that were winnowed from 332 white papers. The funding was $191 million over five years.[23] The topics of the proposals are guided by the details of the calls and so are aligned with the needs of the three services. The work is very much at the frontiers of knowledge. In 2011 the Army Research Office awarded eight MURIs. The topics included quantum science, biologics, nanotechnology and atomic layers, and light in filaments.

Centers of Excellence at ARL

The Army has long made awards to certain university programs of interest for topics rather than for individual investigators. Examples are:

- High Performance Computing at Stanford, Morgan State, University of Texas, El Paso, *inter alia*.
- Flexible Displays at Arizona State University.
- Materials research at the University of Delaware and Johns Hopkins University, *inter alia*.

The rationale for each center varies but they are all attempts to broaden expertise that the ARL needs or will need. Some have close collaboration simply because of a close geographical proximity to an Army laboratory, which helps to make interactions easier to manage. The centers involving the University of Delaware and the Johns Hopkins University are fairly close to the Aberdeen Proving Ground where the Army's materials research is done. ARL staff have been, over the years, close to the two universities. The materials experts at the University of Delaware perfected a key step in the manufacture of the long rod penetrator for the 120mm main gun of the Abrams main battle tank.

The center on flexible displays was transferred from a commercial entity and program run by the Defense Advanced Research Projects Agency. The intention here is to support the industry by strengthening the industry's infrastructure for the manufacturing processes (somewhat similar to the electronics industry's SEMATECH). Funding for the display center comes from the Army tech base, in the form of 6.2 research funding, and from the Army's Manufacturing Technology (MANTECH) program.

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[22] "Institute for Advanced Technology," *United States Army Research Laboratory*, homepage, available at <www.arl.army.mil/www/default.cfm?page=510>.

[23] "DOD Awards $191 Million in Research Funding," *U.S. Department of Defense*, no. 333-11, April 22, 2011, available at <www.defense.gov/releases/release.aspx?releaseid=14432>.

Appendix B - Interviews

The following people have made helpful and substantial contributions to us as we conducted this study:

ARL Personnel

John Pellegrino, Directorate Executive, Computational & Information Sciences Directorate.

Mr. John Eicke, Division Chief, Sensors and Electron Devices Directorate.

Mr. Gregory Cirincione, Computational & Information Sciences Directorate.

Kelvin Oie, Cooperative Agreement Manager, Human Research & Engineering Directorate.

Jon Bornstein, Cooperative Agreement Manager, Vehicle Technology Directorate.

Lyle Schwartz, former Chairman, National Research Council Technology Assessment Board for the Army Research Laboratory

Bret Piekarski, Cooperative Agreement Manager, Sensors and Electron Devices Directorate.

Eric Forsythe, Assistant Program Manager, Sensors and Electron Devices Directorate.

Robert Kokoska, Program Manager, Army Research Office.

David Skatrud, Director, Army Research Office.

Kelly Foster (Strachko), Director's Staff, Adelphi Laboratory Center.

Tien Pham, Subject Matter Expert, Sensors and Electron Devices Directorate.

Others

Patricia Fox, Division Chief, Army Contracting Command, Durham, NC.

Appendix C - Acronyms

AMC – Army Material Command

ARL – Army Research Laboratory

CAM – Cooperative Agreement Manager

CAN – Cognition and Neuroergonomics (CTA)

CERDEC – Communications & Electronics Research, Development and Engineering Center

COE – Center of Excellence

CRA – Collaborative Research Alliance

CTA – Collaborative Technology Alliance

DOD – Department of Defense

DTRA – Defense Threat Reduction Agency

GTRI – Georgia Tech Research Institute

IAT – Institute for Advanced Technology

ICB – Institute for Collaborative Biotechnology

ICT – Institute for Creative Technologies

ISN – Institute for Soldier Nanotechnologies

ITAR – International Trafficking on Army Regulations

MANTECH – Manufacturing Technology (DOD funding to reduce production costs)

MAST – Micro Autonomous Systems and Technology (CTA)

MURI – Multi-disciplinary University Research Initiative

NS – Network Science (CTA)

OSD – Office of the Secretary of Defense

PEO – Program Executive Officer

PM – Program Manager

RDEC – Research, Development and Engineering Center

SBIR – Small Business Innovative Research

SEMATECH – Semiconductor Technology

SIGS – Single Investigator Grants

SOCOM – Special Operations Command

S&T - Science and Technology

TARDEC – Tank Automotive Research, Development and Engineering Center

UARC – University Affiliated Research Center