AN APPROACH FOR EFFICIENTLY MANAGING DOD RESEARCH AND DEVELOPMENT PORTFOLIOS

Drs. Carolyn Wong, Paul Steinberg, Kenneth Horn, and Elliot Axelband

Managing Department of Defense (DoD) research and development (R&D) portfolios is a challenging task today. Not only do defense R&D managers have limited resources to spend on pursuing new technologies, but there is also an active civil and commercial market for some technologies the DoD is interested in. How can the DoD better understand what areas it must pursue on its own and what areas it might be better off collaborating with non-DoD organizations? This article presents a straightforward approach for managing DoD R&D portfolios that can help DoD managers understand how their R&D efforts are allocated, and how they might more efficiently manage them to take advantage of scarce resources and technological capabilities elsewhere. After describing the approach, the authors illustrate it using the example of the basic research technologies part of the U.S. Army's R&D portfolio.

To maintain its technological edge, the Department of Defense (DoD), through its Armed Services and agencies, spent nearly $9.3 billion in fiscal year 1995 on basic, exploratory development, and advanced development research. While in the past, the DoD accepted such research and development (R&D) investments simply as necessary expenditures, today, the DoD faces a series of demands and constraints that argue for more carefully and more efficiently managing that investment: These include:

- future reductions in science and technology (S&T) funding—reductions that have averaged 15 percent per year over the past few years;

- commercial domination of many of the important technological areas for the DoD, such as information technologies;

- growth in international technology capabilities and in competition from European and Japanese companies; and

- a changing research climate within the government, with a growing ideological shift away from big government involvement in R&D.

One of the constraints affecting DoD research investments is clearly resources: Resources to conduct DoD R&D are simply more limited than they were in the past. But even if the DoD had unlimited resources with which to pursue its R&D projects, it is not always clear that the DoD is in the best position to lead in certain technological areas. There is a very active civil and commercial market, both domestic and international, that is pursuing its own R&D activities in the same areas as is the DoD, and in many situations, the commercial and civil sectors are technologically ahead.

Take, for example, global positioning system (GPS) technology. GPS began as an Air Force program to put up satellites to generate radio navigation signals to enhance the navigational capability of military vehicles and guided weapons. The DoD R&D effort in GPS technology spanned decades and consumed billions of defense dollars. Technical advances by the DoD ultimately led to recognition of commercial applications and to DoD's decision to provide a commercially available channel in addition to the secure military one. During the development of GPS technology, advances in semiconductor technology enabled small receivers to be built, and the market for geographic information systems grew rapidly. These changes led to a significant commercial R&D investment in GPS technology.

The end result is that the commercial sector now spends more than the DoD in a technological area that the DoD pioneered and once led. In terms of R&D projects, the DoD now has the opportunity to collaborate with commercial firms in areas of common GPS interest (e.g., the ground-based segment of GPS), thus reducing DoD's need to develop technology available from commercial sources.

Of course, not all technological areas are like GPS technology. For example, R&D in high-energy lasers and radiation-tolerant semiconductors for ballistic missile defense spacecraft are DoD-driven and unlikely to change, since purely commercial firms have little interest in pursuing research in these areas.

Carolyn Wong is currently an operations research specialist at RAND. She holds a Ph.D. degree in electrical engineering (operations research), an M.S. degree in management, and a B.A. degree in mathematics, all from the University of California at Los Angeles.

Paul Steinberg is currently a communications analyst at RAND. He holds a Ph.D. degree in English from the University of California at Berkeley.

Kenneth Horn is currently director of the Force Development and Technology Program in the RAND Arroyo Center. He holds a Ph.D. degree in aeronautics and astronautics from Stanford University, and M.S. and B.A. degrees in mechanical engineering from Rice University.

Elliot Axelband is currently a RAND consultant and associate dean at the School of Engineering, University of Southern California. He holds a Ph.D. degree in engineering from the University of California at Los Angeles.

How can the DoD manage its massive portfolio of R&D projects in a way that enables it to understand what areas it must pursue on its own? And in what areas might it be better off collaborating with commercial firms and leveraging off their capabilities? Here we present an approach for managing DoD R&D portfolios that can help DoD managers understand how their R&D efforts are allocated and how they might more efficiently manage them to take advantage of scarce resources and technological capabilities elsewhere. After describing the approach, we illustrate it using the example of the U.S. Army's R&D portfolio, looking particularly at its basic research technologies.

THE DOD R&D ASSESSMENT MATRIX: A TOOL FOR MANAGING R&D PROJECTS

In thinking about a useful way to help DoD research managers categorize varying projects within an R&D portfolio and manage them effectively, we developed an approach that involves using a two-dimensional matrix that is partitioned into four management domains (Saunders et al., 1995; Wong, 1998).[1] This matrix is designed to serve as a tool to obtain a first-order indication of which defense technologies might overlap with commercial technologies.[2] Below, we discuss the two dimensions and the four management domains in more detail.

MATRIX DIMENSIONS

Two dimensions are critical to categorizing any DoD R&D technology area: the technology's utility to a military Service or DoD agency, and, since many DoD technologies are being pursued by commercial firms, the technology's market breadth.

The Service or DoD agency utility dimension reflects the potential contribution of the technology to helping the Service or DoD agency accomplish its mission. In our framework, Service or DoD agency utility is represented as a continuous scale that ranges from low to high. An example of a technology that would have low Service or DoD agency utility is one that is not expected to contribute directly to maintaining DoD's future defense capability. On the other hand, a technology that is critical to conducting future defense operations is an example of a high Service or DoD agency utility technology.[3]

> "The market breadth dimension is designed to indicate the level of interest outside DoD in a particular technology."

The market breadth dimension is designed to indicate the level of interest outside DoD in a particular technology. If a technology has many potential government and commercial uses (i.e., everybody wants it), then industry's interest is likely to be higher than if the technology had potential use only for a particular military Service or DoD agency (Service- or DoD agency-unique). Industry's interest in the former case is likely to be higher, since advances in the technology have potential uses in many products or services. Hence, industry is likely to perceive such a technology as one that is more likely to result in higher profits. In our framework, market breadth is represented as a continuous scale that ranges from a technology having potential uses to a particular military Service or DoD agency only (Service- or DoD agency-unique), to potential government uses only, to potential government and commercial uses (generic).

DEFINING MANAGEMENT DOMAINS

Technologies that have a moderate to high utility rating will fall into the upper half of the matrix framework. These technologies are generally vital to the successful completion of a Service or DoD agency's mission. The Service or DoD agency will most likely want to be active and maintain some control (e.g., through funding) over the R&D activities that occur in these technologies. At the same time, technologies whose market breadth is limited to the government will fall into the left-hand side of the matrix. The government is less likely to find suitable industrial partners in these technologies because commercial interest is limited. Hence, government funding is likely to be required for R&D to occur in technologies that fall roughly in the region called the lead domain in Figure 1.

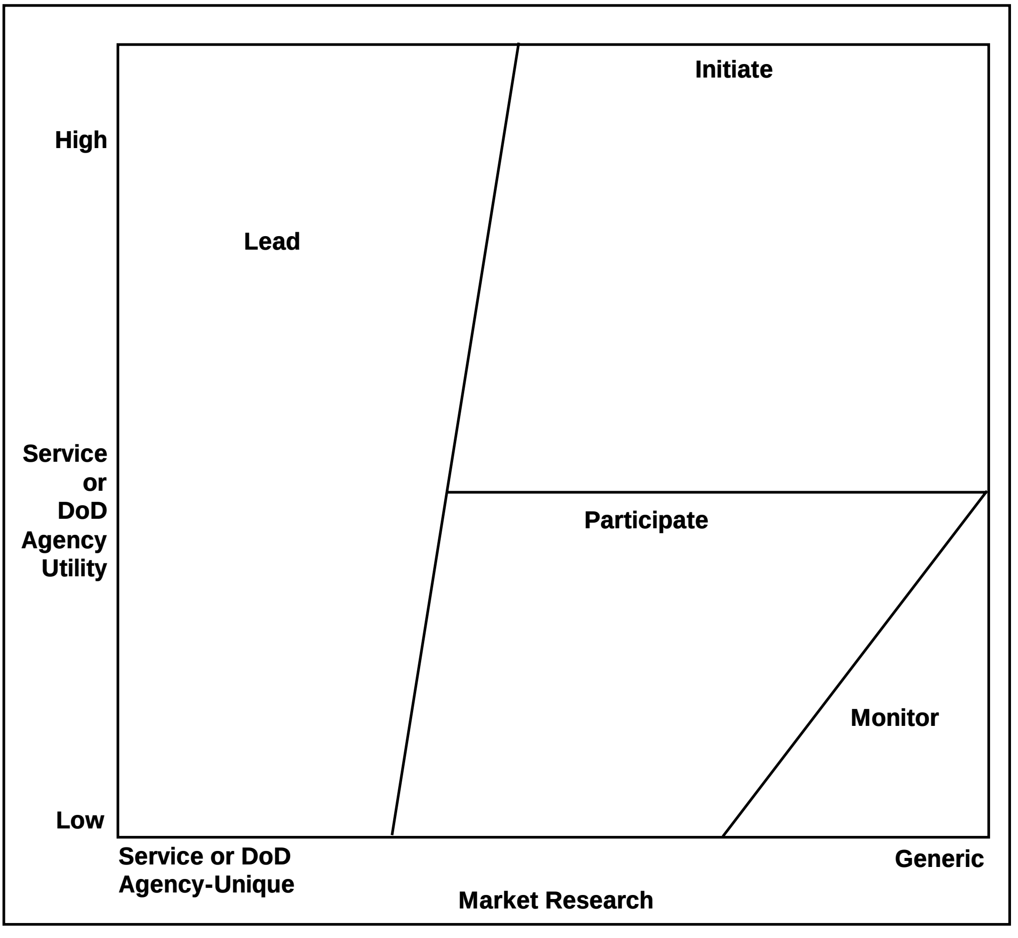

Figure 1. Management Domains Within Assessment Matrix

Since industry interest is required for collaboration to be successful, the right-hand region of the matrix framework, where industry interest is moderate to high, is the general area where collaboration is likely to work. Under tight fiscal constraints, however, a Service or DoD agency may find that it must dramatically lower or eliminate its R&D funding in some technologies. We argue that the candidates for reduced funding are those with low Service or DoD agency utility—that is, those in the lower half of the framework. Among those with low utility, those with high industry interest (i.e., technologies in the right-hand side of the framework) may be better candidates for lowered funding because R&D is more likely to be continued in those technologies through industry funding. R&D activities are unlikely to continue in Service- or DoD agency-unique technologies without government funding. Hence, technologies that are the best candidates for reduced funding fall roughly in the region called the monitor domain in Figure 1.

The remaining area on the framework in Figure 1 is divided into two domains: initiate and participate. Technologies that fall into the initiate domain have higher utility; hence, the government may want to spend more funds and effort to ensure that research in these technologies accomplishes government goals. Technologies that fall into the participate domain have lower utility; as a result, the government may be more willing to compromise on a set of goals in exchange for the benefits a collaborative effort would bring.

The Services and DoD agencies have traditionally judged the progress and success of R&D efforts in terms of three benchmarks—performance, schedule, and cost and budget[4] characteristics. As Figure 1 shows, our framework comprises four management domains, which reflect different approaches to managing the three benchmarks.[5] Our discussion below is presented from DoD's viewpoint.

Lead Domain

For those technologies in the lead domain, the Service or DoD agency should expect to spend its own funds to realize the benefits of technological advances.[6] When a Service or DoD agency chooses to lead, it defines the performance goals, provides the vision, and specifies the potential products or capabilities. The Service or DoD agency also sets forth its schedule requirements and sets the resource (cost and budget) constraints. Under a Service- or DoD agency-lead management approach, the DoD group uses contractual measures to control performance, schedule, and use of resources (budget). In the lead role, the DoD group is conducting "business as usual," and the contracted activities are usually not collaborative.

> "For those technologies in the lead domain, the Service or DoD agency should expect to spend its own funds to realize the benefits of technological advances."

Initiate Domain

Technologies that fall into the initiate domain have high DoD agency or military Service utility and high industry interest. Although industry might be funding R&D in these technologies, the DoD might not wish to just stand by and rely totally on industry to meet DoD goals.

Instead, a Service or DoD agency may want to actively seek and initiate collaborative R&D efforts to ensure that R&D in these areas addresses its goals.

When a Service or DoD agency chooses to initiate, it defines its performance goals, provides its vision, and specifies products and capabilities of DoD interest. The Service or DoD agency may also set forth its schedule requirements and set its resource (cost and budget) constraints.

In its search for a collaborating partner in industry, the Service or DoD agency may look for areas of intersection among its performance goals and those of potential industrial partners, rather than negotiate a set of goals, since these technologies are primarily of high Service or DoD agency utility. The DoD group may also look for compatible schedules or negotiate an acceptable schedule and may also negotiate a set of resource constraints. Under a DoD-initiate management approach, the Service or DoD agency tries to control performance, but may share control of schedule and use of resources. In the initiate role, the DoD group is collaborating with industry. In such an effort, it should achieve the same or nearly all the same goals it would achieve if it conducted the activity without collaboration.

"Under a DoD-initiate management approach, the Service or DoD agency tries to control performance, but may share control of schedule and use of resources."

PARTICIPATE DOMAIN

Technologies in the participate domain have moderate market breadth and moderate Service or DoD agency utility. Under tight fiscal constraints, neither the Service, DoD agency, nor industry will have enough funds to invest much in these technologies. Collaboration may allow the Service or DoD agency and industry to pool resources to perform R&D in these areas. However, the Service or DoD agency may not want to expend additional efforts to actively seek and initiate research activities. For technologies in this domain, both the Service or DoD agency and industry can design and participate in activities for mutual benefit. Such efforts may require both the DoD group and industry to compromise on a set of R&D goals. Without a willingness to adjust goals, a joint investment may not be attractive enough to the Service or DoD agency or potential industry partners.

When a Service or DoD agency chooses to participate, it may negotiate acceptable performance goals if it cannot find an appropriate intersection with industry performance goals. The Service or DoD agency may also negotiate an acceptable schedule as well as a set of resource constraints. Under a DoD-participate management approach, the Service or DoD agency has shared control of performance, schedule, and use of resources. In the participate role, the Service or DoD agency is collaborating with industry and should achieve at least some of the same goals it would achieve if it conducted the activity without collaboration.

MONITOR DOMAIN

Technologies in the monitor domain have low Service or DoD agency utility (i.e., do not contribute directly or very much to its overall mission) and high market breadth. Under tight fiscal constraints, the Service or DoD agency may have to

Table 1. Benchmark Characteristics of Management Domains

Management Domain	Characteristics • Performance • Schedule • Resources	Effects • Control • Collaboration
Lead	• Define performance goals, vision, products, capabilities • Set schedule • Set resource constraints (e.g., budget)	• Service/DoD agency has full control and responsibility for performance, schedule, and use of resources (e.g., budget) • Usually not collaborative
Initiative	• Define performance goals, vision, products, capabilities • Set or negotiate acceptable schedule • Set or negotiate resource constraints (e.g., budget)	• Service/DoD agency controls performance, but shares control of schedule and sometimes resources (e.g., budget) • Can be collaborative
Participate	• Define key performance requirements and negotiate performance goals • Negotiate acceptable schedule • Negotiate resource constraints (e.g., Army's share of budget)	• Service/DoD agency shares control of performance, schedule, and resources • Should be collaborative
Monitor	• Vigilant communication of performance requirements • Communication of schedule requirements • Little or no resource commitments	• Service/DoD agency has no control of performance, schedule of resources • Service/DoD agency does not have a formal role

let industry take the lead for technologies in the monitor domain and limit its own R&D investment there, restricting its role to one of active monitoring. Active monitoring could include low or no-cost activities, such as establishing working relationships with industry leaders, regularly (but informally) communicating DoD needs in the technology, and attending workshops and conferences. In the monitor role, the Service or DoD agency does not have a formal role and has no control over performance, schedule, or use of resources committed to R&D activities.

Table 1 summarizes typical performance, schedule, and cost benchmark characteristics and control and collaboration effects of the four management approaches in the matrix. As noted earlier, the demarcations between the management approaches are fuzzy.

Applying the Approach: The Example of the Army's Basic Research Projects

To show how the approach works, we use the Army as the Service or DoD agency, focusing on the Army's basic (6.1) research projects as an example application.[7] As such, we use the list of technologies found in the Army's fiscal year 1995 Research, Development, Test, and Evaluation (RDT&E) Program (known as the R–1) under the basic research heading (OCDoD, 1994). We limited our considerations to those technologies that showed a positive funding level for fiscal year 1995 (proposed). The list of Army basic research technologies is shown in the box on page 347.[8]

How the Basic (6.1) Research Technologies Were Placed Using the Approach

Using the technologies shown in the box, we placed them on the matrix assessment framework with the help of a group of researchers with backgrounds in engineering, operations research, business management, and the physical sciences. Experience levels ranged from five years to decades of experience in R&D issues. Every researcher had worked on Army R&D projects for at least several years, and all were familiar with the Army's current R&D program. In addition, most researchers had experience with commercial firms that did business with the Army.

> "For computational convenience, researchers assumed a scale of zero to three for the market breadth axis and for the Army utility axis."

Each researcher was furnished with descriptive material on the technologies. To minimize the influence of current budget allocations on the placement of technologies on the framework, no budget information was included in the descriptive material, nor was it discussed or analyzed until the conclusion of iterative discussions to resolve differences in opinion on where some technologies should be placed.

Each researcher also received guidance on how to interpret the endpoints of the market breadth and Army utility dimensions of the framework.[9] For the market breadth axis, placement on the left-most portion of the framework indicated "close to Army unique" and placement in the right-most portion indicated "close to government and commercial uses" (generic). For Army utility, placement on the lower portion of the framework indicated that the technology's potential contribution to accomplishment of the Army's mission is low or small. For example, technologies that do not directly contribute to maintaining future combat capabilities should be placed near the bottom. Placement at the top of the framework indicates that the potential contribution the technology is expected to make is great (e.g., technologies that are critical to future combat effectiveness).

For computational convenience, researchers assumed a scale of zero to three for the market breadth axis and for the Army utility axis. A market breadth value of zero indicated potential Army uses only (Army unique), and a market breadth value of three represented potential government and commercial uses (generic). Similarly, an Army utility value of zero indicated low Army utility, and a value of three indicated high Army utility.

For each basic research technology shown in the adjacent box, each researcher

Army Basic (6.1) Research Technologies in the R–1
Artificial intelligence technology
Aviation technology
Ballistics technology
Chemical, smoke, and equipment defeating technology
Combat vehicle and automotive technology
Command, control, and communications technology
Computer and software technology
Electronic survivability and fuzing technology
Electronic warfare technology
Electronics and electronic devices
Environmental quality technology
Human factors engineering technology
Joint services small arms program
Laser weapons technology
Logistics technology
Manpower/personnel/training technology
Materials technology
Medical technology
Military engineering technology
Missile technology
Modeling and simulation
Night vision technology
Nonsystem training device technology
Weapons and munitions technology
Note: Army Basic Research includes four classified programs not shown in the table.

specified a market breadth value and an Army utility value. Each researcher worked independently to establish his initial values, with one researcher tabulating the results. The tabulated results showed consensus in most technology areas. For example, all researchers specified values for environmental quality technology that placed this technology in the monitor domain. Similarly, all researchers specified values for medical technology and computers that placed these technologies in the initiate domain. In addition, all researchers specified values for all classified programs that placed these technologies in the lead domain. However, there were also some technologies for which there was no initial consensus. For example, some researchers viewed night vision as a lead domain technology, while others felt that it was an initiate technology.

"To resolve these differences, the researchers held a series of discussions to try to reach a consensus."

To resolve these differences, the researchers held a series of discussions to try to reach a consensus. For this exercise, we considered "widely different values" to be values that differed by more than 0.5 and placed the technology in a different domain. The discussions methodically moved from one technology to the next, but the placement for some technologies required multiple discussions. The discussions took place once a week for about a month. For this exercise, we viewed values that would place the technology in the same management domain as a consensus. Hence, researchers could adjust their specification of values to reach consensus but still have some leeway to express their opinion about where the technology should be placed on the matrix.

The discussions resulted in modified values for some of the technologies by some researchers. Any remaining discrepancies were adjudicated by the group leader. After the discussions, we averaged the market breadth values and the Army utility values for each technology in each category. The pair of average values for each technology in each category determined the technology's placement on the framework.

RESULTS OF PLACING THE BASIC (6.1) RESEARCH TECHNOLOGIES USING THE APPROACH

Figure 2 shows the end result of the exercise of placing the Army's basic research technologies. We clearly see that the Army's basic research R&D is not a mass of homogeneous technologies. Of the 24 technologies considered (not counting the classified programs), only 6—one quarter—are categorized as having both a high Army utility and as Army unique in terms of market interest. Half of the technologies are both of high Army utility and of interest to nondefense industries, and another fifth of the technologies are both of moderate Army utility and moderate interest to industry. Only one technology is of low utility to the Army and high interest to industry.

This distribution of technologies shows that it may make sense for managers to take different approaches in managing the technologies. For example, those six technologies in the lead category are basically core Army R&D, technologies that are not of interest to industries other than some

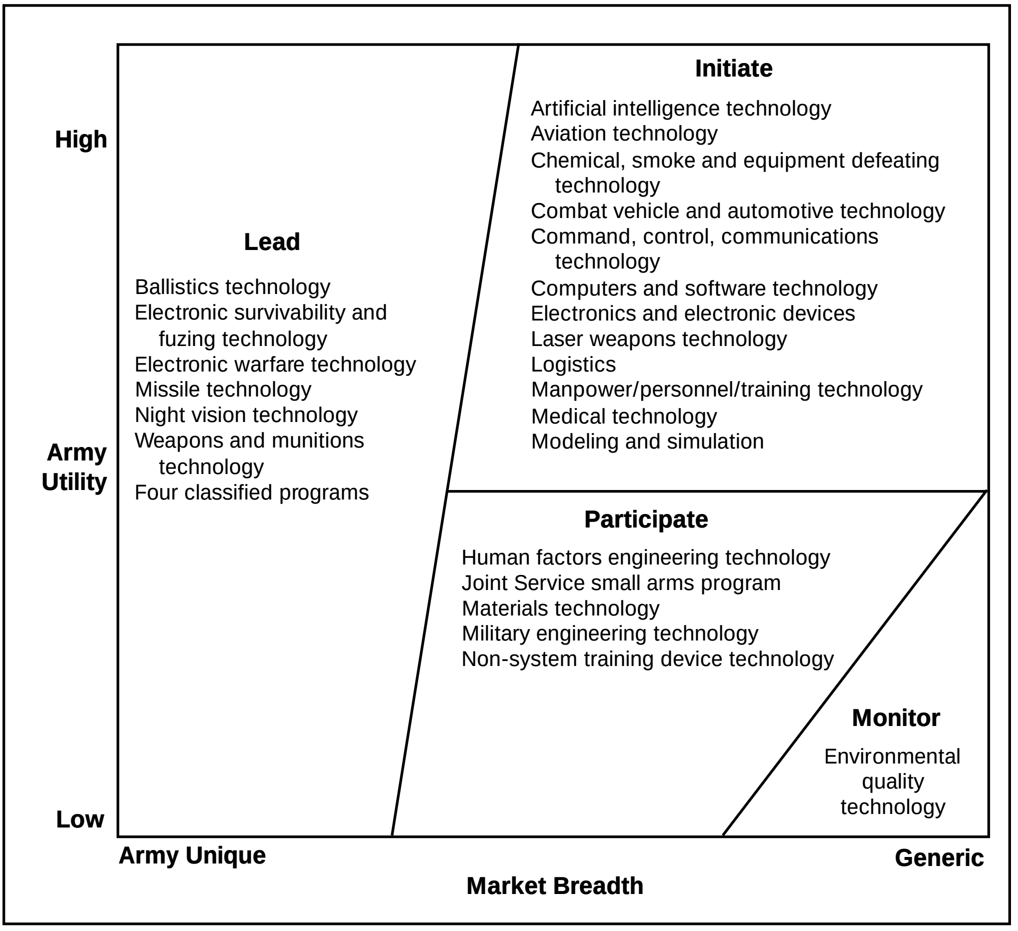

Figure 2. Placement of Basic (6.1) Research Technologies

military suppliers and ones that the Army likely has a strong technological lead in. These technologies will require complete Army funding and can be managed using basic contract mechanisms with traditional military suppliers.

However, the 17 technologies in the initiate and participate categories—which together represent nearly 75 percent of the total—are technologies in which the Army and nontraditional military suppliers in the commercial world have a mutual interest. Such technologies offer the potential for collaboration with industry, in some cases to save resources and in some cases to leverage off technological leads held by industry.

In fact, the Army has already started collaborative efforts to develop some technologies that fall into the initiate and participate domains. For example, in Project Plowshares, the Orange County, FL, local government is using Army-generated computer simulations to aid in disaster relief. And the Army Tank-Automotive and Armaments Command (TACOM) has collaborated with the Big Three automobile manufacturers to form the National Automotive Center (NAC). Army and industry collaborative efforts are also ongoing in the information technology area.

Managing such collaborations will require something other than the standard contracts used for traditional military suppliers. To this end, cooperative agreements (CAs) and especially other transactions (OTs) are instruments more suitable for collaborative efforts. In 1989, Congress authorized CAs (in 10 U.S.C. §2358) and OTs (in 10 U.S.C. §2371) for use by the Defense Advanced Research Projects Agency (DARPA) as alternative mechanisms for conducting R&D. Authority to use CAs and OTs was extended to all of DoD, including the military Services, in 1991.[9] U.S. Code §2371 includes the category of "other transactions" as an essentially undefined term. DARPA has interpreted Section 2371 to mean that OTs are a class of transactions outside the procurement and assistance categories, and DARPA has implemented them as such since 1989, the time of the statute's original enactment.

"...there was consensus that environmental technology belonged in the monitoring category, since developing the technology is clearly not central to the Army's warfighting mission and the technology itself is well developed by commercial companies."

As mentioned above, there was consensus that environmental technology belonged in the monitoring category, since developing the technology is clearly not central to the Army's warfighting mission and the technology itself is well developed by commercial companies. While the Army will need to use the technology to deal with the environmental problems it faces on military bases, staying in touch with what is going on in industry and outsourcing as appropriate would seem to make more sense than developing the technology in-house.

Although not shown here, the distribution of the Army's exploratory development (6.2) technologies shifts toward the left side of the framework in the direction of the lead domain: lead, 30 percent; initiate and participate, 70 percent. This finding indicates that in addition to the collaborative opportunities in basic research technologies, the Army also has many potential opportunities to collaborate with industry in exploratory development technologies.

The distribution for advanced development (6.3) technologies shows a more marked shifted toward the left side of the framework: lead, 70 percent; initiate and participate, 26 percent; monitor, 4 percent. This finding is consistent with expectations. As a technology progresses from basic research, to exploratory development, to advanced development, and on to an identifiable product, the research becomes more specific in terms of its military application; hence, fewer collaborative research opportunities with industry would be expected. Therefore, the use of the matrix evaluation tool correctly indicated the expected decline of collaborative opportunities with industry as research progresses to a military product. However, the finding also indicates that more than 30 percent of the advanced development technologies are still good collaboration candidates, so ample opportunities for the Army to perform research with industry still do exist for advanced development technologies.

Discussion

The application of the approach shows its value as a management tool. In a time of diminishing resources, being able to categorize R&D efforts into the four management domains can enable resources to be saved or reallocated. For example, while R&D efforts that fall into the lead category must be funded in entirety, those that fall into the initiate or participate domains can be cost-shared with industry; those funds can either be saved or used elsewhere to fund other R&D efforts. In addition, R&D efforts that fall into the monitor category require no real allocation of resources beyond what is necessary to keep abreast of the industry; thus, any excess resources could again be saved or diverted to R&D efforts elsewhere in the organization.

The ability to categorize R&D efforts into management domains also has some applicability as to how the efforts themselves are managed. While efforts in the lead domain lend themselves to standard contracts involving traditional military suppliers, those in the initiate and participate domains lend themselves to collaborative efforts using CAs and OTs. There may be some efficiencies and economies of scale to managing like efforts together—for example, all contract-based efforts versus all OT-based efforts.

In fact, the government has recognized that there are potential efficiencies to manage these collaborative efforts together and is anticipating a substantial increase in the use of collaborative instruments such as CAs and OTs. This recognition is made apparent by recent changes implemented by the Defense Contract Management Command (DCMC). DCMC has designated four regional offices to administer the Post Award Authority (PAA) of OTs and CAs and developed specialized expertise to do it. This new service is being provided to both the Services and to DoD agencies, such as DARPA. To facilitate the provision of this new service, DCMC will also provide limited assistance with pre-award negotiations where the use of CAs and OTs is being considered.

Our study shows that there are many technologies where the Army can benefit by performing collaborative R&D with industry. By using contractual instruments such as CAs and OTs and by taking advantage of the new services being offered by DCMC, the DoD has the tools to realize the benefits offered through DoD-industry R&D collaborations.

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ENDNOTES

1. We examined a number of alternatives in our search for a tool. Ultimately, we adapted the concept of an alternative that was developed to categorize Navy technologies. See Saunders et al. (1995). For adaptation details on how the concept was adapted, see Wong (1998).

2. Defense transition from full funding and control of R&D to collaborative R&D with industry will require DoD organizations to examine each R&D technology area and decide whether it might be a candidate for collaborative efforts. The matrix described here is designed as a tool defense organizations can use to gain a first-order cut at which areas might be worth investigating as collaboration candidates. The matrix is not designed as a decision analysis tool to make definitive R&D project funding decisions. A decision on whether to collaborate and on the extent of defense funding contributed toward any collaborative effort would, of course, need to be made on a project-by-project basis after considering many factors, including the availability and suitability of industry partners, the precise areas of overlap, benefits to the government, security considerations, funding requirements, and schedule constraints.

3. We envision that individual DoD agencies and military services can use the matrix tool to determine which areas are collaboration candidates for a particular organization. Conceivably, a technology area that is a good collaboration candidate for one DoD group might not be for another DoD group because of different focuses, priorities, etc. In addition, using the tool effectively requires that the government be current and aware of the R&D that industry is performing in the technologies being considered for collaboration. This requirement can be met through the government experts who perform the "smart buyer" function, since adequate performance of this function requires both in-depth knowledge and currency.

4. We use the more general term "resources" to include cost and budget.

5. The domains shown in the figure have fuzzy borders. There is no line or curve on the framework above, below, left, or right of which a particular management approach can be judged most appropriate.

6. Government funding is likely to be needed for technologies in the lead domain because the market breadth of these technologies is limited to the government. This means that, for the most part, commercial applications of the technology have not yet been recognized. Hence, the government might not be able to find industry partners to collaborate with in pursuing these technologies.

7. Our focus here was on basic research (i.e., 6.1 activities); the other two S&T areas are exploratory development and advanced development, known as 6.2 and 6.3 activities, respectively.

8. The names of the technologies in the box are the names used in the R–1. Although the names of the technologies are generic, our placement of the technology on the matrix framework is based on the specific R&D activities that were funded by the Army during fiscal year 1995. That is, our placement of the technology does not imply that all research that might fall under the generic name would be in the domain shown in our Army illustration.

9. The matrix described earlier was modified to reflect the Army.

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