

15 The Challenge of Defense R&D: The Role of the University

Gerald J. Iafrate

This chapter evolved from my 32 years of career experience in the Department of Defense (DoD) research and development establishment and my follow-on career as a professor at the University of Notre Dame. I will discuss the current challenges for the Department of Defense in light of the power of the university, focusing on how they can work together in partnership to meet some of these challenges.

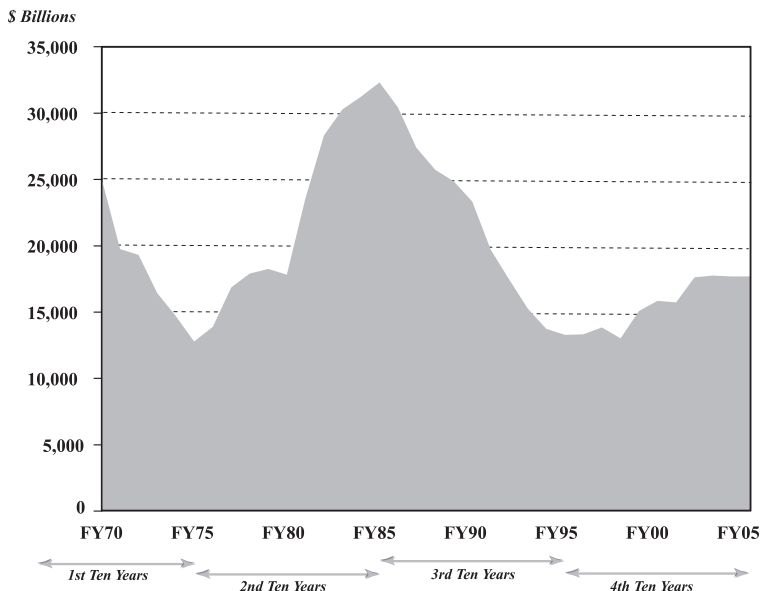
The Challenges

Three intertwined issues drive the research, development, and acquisition (RDA) train. These issues are: the perceived threat, the political climate, and economic realities. They change over time in a quite interesting way.

Figure 1 shows how the Army RDA budget has moved up and down like a roller coaster in the past 35–40 years. The reason for the swings basically comes from acquisition considerations. The science and technology (S&T) base does not vary much percentage-wise over that time frame in real dollars, but the acquisition dollars vary wildly. However, while the basic research money does not change dramatically, the pressure placed on basic research and those who execute it does change dramatically when you are in the troughs versus when you are at the peaks.

Gerald J. Iafrate is a professor of electrical and computer engineering at North Carolina State University. At the time of the Colloquium, he was a professor of electrical engineering at the University of Notre Dame. This article is based on remarks delivered at the 26th Annual AAAS Colloquium on Science and Technology Policy, held May 3–4, 2001, in Washington, DC.

Figure 1
Army RDA Budget Dynamics



For example, in the good times (the peaks), the budget increases. When we perceive a threat like Sputnik in 1958, or the Soviet Union in the 1980s, science and technology thrives and the “dare-to-fail” approach is tolerated. During this time, acquisition thrives and notional and next-generation systems are defined. The infrastructure builds up to meet the demands posed by the threat.

In challenging times (the troughs), the budget decreases because the threat has been reduced. For example, we entered a trough when the Berlin Wall fell in 1989. Funding for science and technology is still fairly stable but it now focuses on the near term because the money that came from acquisition and major modernization influences is now gone. New systems are de-emphasized and funding for infrastructure is reduced. Science and technology needs to pare back and find savings. The emphasis is on efficiency and affordability.

Managing this kind of change is a critical challenge. Today we are seeing change as we speak because the new defense strategy is still to emerge. Over that 35–40 year period, the industrial-military complex has moved to a free market, global economy. Changing threats have emerged both abroad and at home. In addition, the Department of

Defense is faced with changing roles and missions. (These roles and missions are now in review and still to be articulated.) The RDA budget is still resource-constrained. And we are still working with the 1990s defense strategy of power projection, which means we focus power and resources from the United States to faraway places accomplish military missions. The bottom line is that science and technology is key to managing this change.

In the words of William Perry, when he was Secretary of Defense, "There is a moment in time when a door opens and lets the future in. The end of the cold war opened that door and ... by our actions we can shape the future instead of being shaped by it." This is, indeed, an age of opportunity. Change is abound. With the appropriate leadership and the focus on what is important we can shape our destiny in a very prolific way.

Technology

Technical challenges come with being a power projection force. Figure 2 enumerates those challenges now faced by the Army, although they are sometimes horizontally integrated to the other services. These challenges capture the needs to be ultra lightweight, but lethal and survivable; as well, they also reflect on the need to have self-contained, portable power, and to be able to achieve information dominance through sensors and electronics technology. In the main, there is a critical need to develop fuel economic propulsion, logistics efficiency, and heavy lift capability for long range and rapid deployment.

We need specialized tools to accomplish the power projection mission, but many of these tools do not exist today. For a smaller, power projection force, we need science and technology to deliver the necessary capabilities. Figure 3 shows some of the key technology capabilities.

Those technology capabilities meet fundamental mission needs: information dominance. Chemical/biological defense is becoming more of a concern. Simulation and modeling are becoming more important since they enable us to assess the dominance of the battlefield without spending money on a full-scale training exercise. Enhancing the individual soldier is key since we have 500,000 of them; if we enhance one soldier's fighting capability by a factor of ten, we then achieve a major force multiplier enhancement collectively.

In the long-term, the forecast of technologies to exploit over the early part of the new millennium include the information explosion, computer-based simulation and modeling with interactive visualization,

Figure 2 Technical Challenges

- Ultra Lightweight; Lethal and Survivable
- Low Power, Portable Power
- Information Dominance
- Total Situational Awareness
- Survivable Space Assets
- Propulsion Efficiency
- Fuel Economy—Logistics Ease
- Heavy Lift Capability with Long-range Rapid Deployment

designing materials based on nanoscale manipulation of atoms and molecules, and using bimolecular principles for new material properties and functionality. This embraces MEMS (MicroElectroMechanical Systems) as well as other enabling technology on the micro scale.

The University

What is the business of the university? For most universities the first priority is to educate the future work force in the basic sciences and engineering. Second, the university must understand and articulate science and engineering principles and concepts and explore the potential of these principles and concepts for utilization. The third priority is to conduct research as an integral part of the educational process. Private schools basically rely on these three principles to conduct business. Some universities, especially large land-grant schools in some of the states, have incubators and interaction with industrial complexes, but that is not a common university paradigm.

High on every university's list of priorities is the ability to conduct research in a multidisciplinary fashion, that is, across multiple departments. In the mid-1960s, and through the 1970s, the single-investigator program was a major source of research progress. Today, opportunities for significant research come from multidisciplinary efforts. Joint efforts involve teams of faculty from different disciplines

Figure 3

Technology Capabilities

- Portable, All-electric Power
- Line-of-sight Communications
- Automatic Target Recognition
- Command/Control/Communications
- Chemical/Biological Defense
- Ground-based Satellite Communications
- Lightweight, Small, Lethal, Survivable Combat Vehicles
- Unmanned Ground and Air Vehicles
- Simulation for Technology, Training, Tech Assessments, and Wargaming
- Individual Soldier Enhancements

Long-Term Forecast

- Information Explosion
- Computer-based Simulation and Visualization
- Control of Nanoscale Processes
- Chemical Synthesis by Design
- Design Technology for Complex Heterogeneous Systems
- Materials Design through Computational Physics and Chemistry
- Use of Hybrid Materials
- Advanced Manufacturing and Processing
- Principles of Biomolecular Structure and Function
- Principles of Biological Information Processing
- Environmental Protection

who focus on common research objectives. With the advent of university research initiatives from the Department of Defense and other multidisciplinary initiatives from the National Science Foundation, the National Institutes of Health, and other agencies, the tendency is to form clusters of professors from various departments and even different institutions. We see “block” efforts of two to four faculty members, “Centers of Excellence” with 10 to 15 faculty members, and “institutes” with 25 to 40 faculty members. Of course, even when we have only two to four faculty, we multiply each faculty member by three or four students and postdocs; when we have any kind of “block”-type unified effort, we have a substantial number of people working on projects synergistically.

The benefits of multidisciplinary research are many. Individual universities can address hot fields with funding potential. They can look at research and seams that cut across various disciplines. They can address interesting problems and push the envelope of “the art of the possible” in science and technology.

Multidisciplinary research also brings a collective benefit for faculty. Many faculty members begin to work together and learn to understand one another’s vocabulary. They also find a richer cross section of industry research problems. There is a very strong educational component as well. Students get to see science across several domains, as well as engineering applications of that science. Thus, the educational process is advanced. Above all, we look for industrial liaisons so we can transfer technological ideas and, even more importantly, transfer students into jobs where they can improve the Nation’s quality of life, competitiveness, and defense posture.

I have identified four university strategic research trends. First, a university’s vision is to become a premier educational institution and a first-tier research enterprise. Second, the strategy to enhance research is to develop banner areas based on core competencies and to develop a strong link between research and the educational process. Third, a typical university has two goals over a three to five year period; one is to be competitive for research funding from the agencies, the other is to develop industrial links for research and education and to transfer trained students, as well as research, to industry. Fourth, a typical university’s plan is to match core strengths to market demands. Universities can do this by encouraging faculty to seek multidisciplinary efforts and shape interests in emerging fields. Universities must also target faculty hires toward the new banner areas so that five years from now they are prepared to be competitive in hot areas that have promise as new banner areas.

Ultimately, endowment helps a university reach its goals. Many of the premier schools in the country are beginning to enjoy endowments on the order of hundreds of millions of dollars. When a university secures an endowment of that nature, it can readily move to the next plateau quite easily, maybe even above that to new plateaus. Those who can attract endowment and benefactors can do a lot with that investment.

The University of Notre Dame is developing the following banner areas: nanoscience and technology, molecularly engineered materials, high-performance computing, wireless communications, hazardous mitigation, aerospace fluid dynamics, environmental technology, and intelligence systems and control. In every one of these areas, we have developed a champion, a professor with acknowledged expertise in the area who carries the leadership role of attracting other faculty members in order to crystallize this area as a banner area.

Figure 4 compares the mix of players that participate in each sector of the research and technology enterprise. They are an interesting and diverse group. In many ways, they move out of phase with one another, so getting together and working as a unit can be very challenging. In every one of the categories the key characteristics that cut across are very different, and they have a different *raison d'être*.

Over the years that I spent at the Army Research Office, both Republican and Democratic Administrations worked very hard to close the gap between sectors. Acquisition strategies, new modernization approaches, dual-use applications, and COTS (commercial off-the-shelf) products are always trying to close the gap between the defense sector and the industrial sector. Even though they have worked hard at doing that, lots of challenges and problems still exist, especially if you want to develop heavy classes of engines that will carry a 50-ton vehicle, for example. How you get the commercial match to do that is sometimes difficult.

In my later years at the Army Research Office, we started developing various paradigms for cooperative research in which the university, the Department of Defense, and industry come together with a common objective to address problems and find solutions that meet DoD requirements. In the early stages we called these federated laboratories. Today we call them cooperative alliances. The university's goal is to educate the work force, develop advance concepts and principles, and encourage the understanding and application of these concepts and principles. Industry provided application and test beds, manufactured the technology, made it affordable and robust, and developed dual-use markets. In

Figure 4
Sector Comparisons

| Universities | Closing the Gap | |
|----------------------|--------------------------------|---|
| | Defense Industry | Commercial Industry |
| Many Customers | Monopsony: Few Customers | Free Market: Many Customers |
| Education | Low-volume Manufacturing | Service Industry and High Volume Manufacturing |
| Long-term Investment | High Unit Cost | Low Unit Cost |
| Science | High-tech Edge | Customer Products |
| Long View | Near-mid Term | Short Term |
| Research \$ | Large R&D \$ | Low R&D \$ |
| Knowledge | Swift, Low-casualty Victory | Profit |

this paradigm, DoD could meet its mission requirements and capability needs by tailoring the science and technology to mission needs.

That is one great paradigm among other types of paradigms that have developed within the agencies to try to get these three sectors to work together to solve mission-related problems. We need all of their strengths coming to the table.

Conclusion

Science and technology will surely shape the future of the Department of Defense. Science and technology can enable DoD to address all of the challenges and changes it faces. DoD science and technology will continue to underpin both national security and competitiveness.