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The Changing Landscape of Defense Innovation

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Overview

In a rapidly evolving business environment, many successful companies have transformed themselves by reexamining their core missions and competencies and exploiting innovation in nontraditional ways. General Electric still manufactures products but now identifies itself as a services company. Wal-Mart has become the premier retailer by capitalizing on its logistics and support systems. These two giants and other companies have realized that they can become more profitable by exploiting new regions of the business landscape.

Applying this business model to national defense, the innovation landscape can be said to have three regions: products (airplanes, tanks, ships), processes (integrated systems), and retrofits of legacy systems. While the Department of Defense (DOD) is not a commercial enterprise, nor can it change its critical missions as a private firm might do, it, too, operates in a dynamic environment and should be in a continual process of transformation to adjust to and exploit change. Achieving the right balance of effort in these three regions will pay handsome dividends.

Until recently, DOD has invested most heavily in region one, the acquisition of new hardware based on new technologies. Already expensive to acquire, new hardware is even costlier because of its added complexity and need for extensive contractor support. To increase value realized from defense investments, the authors recommend shifting some resources to regions two and three. Creating a framework for exploiting process and retrofit innovation would provide significant increases in capabilities while facilitating successful integration of new product technologies into the existing infrastructure.

Technological innovation is central to the American way of war. In the Cold War, superior technology compensated for American numerical inferiority compared to the Soviet and Chinese military forces. Since the end of the Cold War, innovation has spearheaded the transformation of the American military into a more agile and flexible instrument of national strategy. Today, important developments are reducing the payback from defense innovation. Two trends in particular stand out.

First, today's weapons and support systems are more complex than their predecessors. Doctrine demands that these systems operate in an integrated framework. The greater demand for specialized expertise and training and the requirement for increased supervision drive up costs. Purchase price has become a smaller percentage of the total cost of ownership as operations and maintenance (O&M) costs have increased. Signs of this are ubiquitous. Shortages of specialist manpower and the need to use scarce military manpower for "tip of the spear" occupations are fueling a whole new industry of outsourcing companies to handle work the military cannot manage in-house. In 2003, Halliburton, a service company, became the Army's number one contractor. Prime defense contractors can now earn more profit from O&M and systems integration than from building weapons. Their corporate strategies are shifting to a different part of the value chain: services and integration, not products.[1]

A second change is that the Department of Defense (DOD) is buying fewer products and more integrated systems, especially information technology (IT) systems. The locus of innovation used to be in airplanes, tanks, and other platforms; incorporating the latest technology in them led to better quality forces and to military superiority. Now the payoff is in getting those platforms to work together better.

DOD has always mitigated the difficulty of buying new systems by employing a creative ability to upgrade and retrofit existing systems to meet changing threats and technologies. New systems, while promising great technological advances, tend to be difficult to start and take many years to develop and buy, with the result that fewer units are purchased than planned. Upgrades often are easier to initiate, fund, and sustain. Military systems are used and improved over decades and are never the same systems that had originally been procured. This is true for all classes of DOD systems. From the B–52, an airframe likely to last five decades or more, to the Multiple Launch Rocket System, which was begun in the 1960s and still is in use, long-lived systems prove that weapons platforms can be upgraded greatly, avoiding the need to launch a new system. Indeed, the DOD spiral acquisition process has at its core the idea of constantly upgrading systems, even as they are fielded. Yet this process is also becoming more complex as integration of systems becomes as critical as the upgrade of individual systems. DOD has a history of improving the performance of systems; the challenge now is to do so at lower cost.

Today, the locus of innovation is in cross-cutting systems, not stand-alone platforms. The space-based infrared system (SBIR), the Navy's cooperative engagement capability (CEC), and many "black" tactical intelligence programs are the new sources of American military advantage. The innovation spotlight has shifted to middleware, grid computing, and sensor integration.

DOD does not do a good job buying these systems, as the case of the Navy-Marine Corps Internet illustrates. This $8.8 billion outsourcing project, run by EDS in Plano, Texas, required the transfer of 67,000 separate Navy software programs to new personal computers. Poor planning marred the project from the start. The contractor did not have security clearances in order, so a large work force was getting paid without working. In addition, Navy specialists were frequently in training or traveling when needed. EDS had not thought through orchestrating this complex undertaking.[2]

Many nonmilitary integrated system purchases also have fared badly. The procurement process is complicated and difficult to manage. For example, the Royal Bank of Canada recently had enormous problems with its IT systems. The bank's 10 million customers could not rely on information contained on their balance statements, which were often erroneous. Malfunctions shut down the bank's payroll deposits, throwing corporate clients into chaos. The errors rippled through the system. Tens of thousands of customers did not receive their electronic deposit paychecks, thereby incurring penalties for late electronic payments to their creditors.[3]

The combined trends of increased complexity and the prominence of integrated systems have many consequences. Money for acquisition and training is reduced because it must be spent to patch together solutions in these areas. Military operations are affected. For example, the large work force that needs to be close to the combat theater to support operations must be fed, protected, and housed. As a consequence, the number of forces actually fighting is usually far lower than the number deployed would suggest. Support work can be outsourced to private contractors, but this creates its own problem, as experiences with EDS and contractors in Iraq have demonstrated.

A fundamental rethinking of defense innovation is called for. The system must move beyond its historical focus on better platforms and devote at least as much effort to process innovations and the retrofit of the huge stock of materiel already fielded. While DOD has always retrofitted or modified weapon systems, retrofitting now involves the integration of systems into systems of systems. This is a big change for an innovation system that has concentrated mostly on turning out new and better weapons.

The legacy innovation system was designed for a world in which technology was new and the costs of inserting it were low. The system has to change to keep pace with a world of pervasive technology and complexity. The implications affect everyone. Large contractors, small defense companies, the military services and their supporting agencies, and DOD all need to get better at process innovation and retrofitting existing technology with new capabilities instead of churning out ever larger numbers of products.

Defense Innovation Systems

The concept of an innovation system has proven useful in analyzing competitive advantage of firms, industries, and countries.[4] An innovation system consists of the dynamics between the major players involved in turning new ideas into widely accepted practices. National innovation systems encompass investment patterns, incentives, and supporting organizations in science and technology—for example, in education. There is no presumption that a national innovation system has been consciously designed, or that its different parts work smoothly together. Many innovation systems have been more the product of accidents of history than of planning. They may contain major disincentives, as well.

Too many organizations never bother to question the innovation systems in which they find themselves, instead assuming that they are fixed and permanent. The Soviet Union in the 1980s assumed that by turning out better aircraft, ships, and tanks, it could compete with the United States. But this grossly underrated the importance of high-technology competition in stealth, missile defense, and precision strike. The Soviet innovation system did not supply engineers skilled in these areas. Rather, their system encouraged central control of increasingly specialized engineering skills focused on more and better platforms.[5]

A defense innovation system is simply that part of the U.S. national innovation system that deals with military and security innovations. This includes institutional actors such as DOD and the services, defense contractors, and supporting institutions such as universities. Investment flows of research and development (R&D), Wall Street valuation of defense contractors, and the amount of dual use are all part of the defense innovation system.

Defense innovation systems offer an important framework for understanding how technology and strategy interrelate. The framework suggests asking fundamental questions about structural relationships, key trends, and the fit of the innovation system with national strategy.

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The Legacy Defense Innovation System

The U.S. defense innovation system originated in the Cold War, replacing the mass-production system used to win World Wars I and II. More than any other factor, the system was typified by the experience curve of the aerospace industry. For decades this industry produced one generation of airplanes and missiles after another that were far better than earlier models. Look at the tremendous technological leap between the F–86 Sabre Jet, the first U.S. Air Force swept-wing jet fighter, and the F/A–22 Raptor Stealthfighter. The Raptor can perform missions never even dreamt of by those who flew the Sabre Jet.

This innovation system has been built around the trade-off of increased performance for increased cost. As long as performance grew faster than cost, innovation paid off. By climbing a steep performance learning curve, the United States gained strategic superiority over the Soviet Union. The United States gained this edge because strategic competition was heavily dependent on the nuclear and air forces balance, two areas which benefited from the aerospace innovation model. The defense innovation system, modeled on experiences in the aerospace industry, was closely aligned with national strategy.

This cost-performance learning curve worked in many areas, but not in all of them. Nuclear weapons performance, early warning radars, munitions, and guided weapons all saw enormous improvements in the cost performance trade-off. However, Army weapons never experienced this escalation in performance. Their problems were different; ground war was less technological and more dependent on human factors than were strategic nuclear or air war. The M–1 Abrams tank was far better than the M–48 Patton tank of the 1950s, but the degree of improvements was nowhere near as great as those achieved in aircraft or guided missiles of the same periods. Many of the criticisms the Army faces today stem from the expectation by DOD and others that its forces should have experienced the same levels of performance improvement achieved in aerospace.

Another area where the learning curve gains of aerospace did not translate was in ship design. Consider the Nimitz and Essex class aircraft carriers. Hull shape, speed, use of composite materials, and stealth do not differ significantly between these two classes. Ship design has never gone through the revolutionary transformations that aircraft design has over comparable time periods.

What might tanks and ships look like if their levels of innovation had kept pace with those of aircraft? The most common objection to the premise of this question is that the physics and engineering of each are so fundamentally different. However, in the Cold War, DOD simply applied the aerospace model of innovation to other areas without considering whether it fit them. There was far less of an imperative for a revolution in military affairs (RMA) for land and sea forces. The Army and Navy were not pressed in the same manner.

Had Cold War competition taken a different direction, this might not have been the case. For example, if the Vietnam War had taken place in the early 1950s, a tremendous burst of innovation would have occurred in counterinsurgency, psychological operations, and small unit ground tactics. Nuclear deterrence and global airpower might not have developed as the core of American strategy, and the aerospace industry would not have become the locus of U.S. defense innovation.

Another feature of the current legacy system is its use of a vocabulary constructed on cost–performance trade-offs. This vocabulary is important; it is the way that DOD organizations communicate with each other. How analysts converse with senior leaders, the metrics used, and the very idea of what constitutes a valid argument are deeply shaped by language. Getting support for an innovation that does not use this language is almost impossible.

Operations research in its varied forms—systems analysis, cost-benefit analysis, programming models, and so forth—is the lingua franca of trade-offs. It works best under conditions of loose coupling and when the payoff of new technology can be confined to one department of the whole enterprise. Used for different kinds of problems, operations research can cause more problems than it solves.[6] Operations research does not work very well when system interdependencies are high or when costs and benefits cut across many separate divisions.

For example, the planning, programming and budgeting system (PPBS) introduced in the Pentagon in 1961 was based on a programming model of industrial firms, such as Ford and General Motors. The automobile industry in the 1950s was low-tech. Its inputs—steel, labor, parts—each had separate cost accounts. Profitability resulted from combining these inputs in the mass production assembly plants of the era. PPBS has been used continuously since 1961, even though the context has changed enormously. Today's military is far more tightly coupled. Jointness, data fusion, sensor integration, and battlespace management are far more important now than they were in previous decades.[7]

A similar development has occurred in the business world. Corporations historically have used discounted cash flow for buying capital equipment. Cash flows and costs could be compared between different machines. For lathes, machine tools, and drill presses, this worked fine. But it did not work for buying IT systems, because benefits and costs crossed department lines. Human resources, production, and engineering all benefited from IT, and all had to chip in to pay for it. Business is only now beginning to develop methods for developing optimal strategies for highly interdependent IT systems.

The New Defense Innovation Landscape

Changing conditions, strategies, and economics mean that a defense innovation system that worked in one era may not work in another. Whereas the benefits and costs of innovation are changing, the U.S. defense innovation system is not.

One of the most important changes today is in the amount of technology already in use. The increasingly technical character of the American way of war began with the aerospace forces but has spread to all forces, because logistics, intelligence, personnel, and other areas have evolved from manual to automated systems. The need to make all these systems work together, when interdependencies are high and force structure (the number of divisions, ships, and air wings) is low, is a key difference from the Cold War. The changes point to the need for a very different innovation system.

New technologies now incur a high insertion cost just to make them work with legacy systems. The Navy Marine Corps Internet has to work with the old IT systems. SBIRS and CEC must work with existing command and control systems. Making this happen often means hiring an army of contractors experienced in both legacy and new systems to install, operate, and maintain everything. As a consequence, O&M costs increase exponentially. Beyond a certain level of technology, small additional technology insertions can ripple through the system, driving up costs. New layers of management are needed to coordinate and deconflict the insertion. Different departments have to be brought together to communicate, which further increases coordination costs.

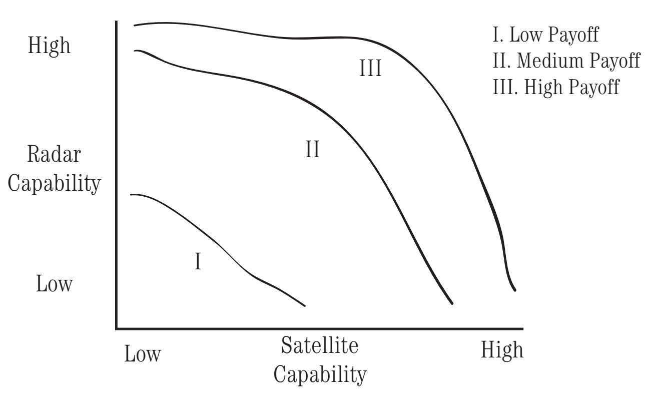
To see how complexity increases costs, perform a little experiment. Wander around your computer center and compare what you see with what you were told a few years back. Computing was supposed to become simpler and safer. It was going to be seamless and "always on." We were promised open systems, self-healing networks, and secure computing. The payoff, according to the visionaries, would be IT systems that required little or no support. They would be like the television and telephone: simple to use.

Does this describe the IT system where you work? We doubt it. The size of the work force at computer centers has skyrocketed. Software is not safer but rather more vulnerable. Help desks, call centers, and local area network specialists are needed to handle all the recent upgrades and software patches. Much of this added IT work is contracted out, but this does not mean that costs have gone down—they have just moved to a different accounting category.

The solution to the problems of increased complexity and buying integrated systems is not to slow the pace of innovation, nor is it to artificially transfer costs to a different category through outsourcing. The answer lies in building capabilities in all different parts of the innovation landscape. An innovation landscape is a graphical picture of the benefit from different combinations of innovations.[8] Advances in radars and satellites, for example, have led to space-based radars, which combine the two technologies.

An innovation landscape for space-based radars is shown in figure 1. Different regions of the innovation landscape (for example,

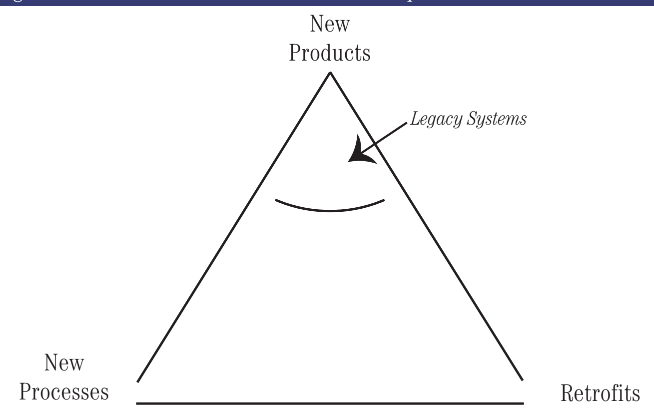
Figure 1. Innovation Landscape for Space-Based Radar



representing regions of high payoff or of particularly attractive technical combinations) can be marked out. These models can be used to explore how strategies, budgets, and risks shape the innovation systems. Innovation landscapes point to questions that might not otherwise be considered and offer a way to move beyond pressuring the current innovation system to produce breakthroughs that it really is not designed to produce

Expanding our field of view of the innovation landscape is critical to coming to grips with the cost trends that are overwhelming DOD. Specifically, a new emphasis on a three-region model of defense innovation is needed to distinguish among new products (airplanes, tanks, ships); new processes (integrated systems); and retrofits of legacy systems. Figure 2 illustrates this landscape as a combination of the three kinds of innovation.

Figure 2. A New Defense Innovation Landscape



Different regions inside the triangle represent the payoff from various combinations of new product, new process, and retrofit innovations. *The central argument of this paper is that the legacy U.S. systems cluster around the top of the triangle (that is, new product innovations)*. This is the world our institutions are built for. New requirements, however, are pulling toward the two bottom corners of the innovation landscape.

DOD has always done all three kinds of innovations; it is the relative balance of effort among these that needs to change. Our great innovation resources such as the Director of Defense Research and Engineering (DDR&E), the Defense Advanced Research Projects Agency (DARPA), the service laboratories, and contractors are all organized for working at the top of the landscape.

Something else also needs to change. The innovation landscape of figure 2 represents a trade space that is rarely considered in current planning. Asking whether the Air Force should buy more Joint Strike Fighters and fewer Raptors is a question that DOD knows how to address. It is a question the current organizations are well prepared to answer, because it deals only with investments at the top of the triangle, with new products and comparisons between them.

The question that DOD and the services are less capable of answering is whether a new weapon, a new integrated system, or a retrofit of a legacy system makes the best investment sense. What are the trade-offs among these alternatives? When is a retrofit better than a new weapon? How can integrated systems complement existing weapons?

For a variety of reasons, such trade-offs are not always done by the existing institutions of DOD. Organizations separated by budget and mission often focus only on their own portions of the triangle (in the case of acquisition organizations, including the

R&D infrastructure, the top of the triangle). They are not treated like the integrated trade space that they are. But this is exactly where new problems lie.

Another way of saying this is that we navigate only a limited region of the defense innovation landscape. For decades, we have systematically focused on the new product area. The reason for this is the legacy of the Cold War-era innovation system. DOD and service organizations, contractors, and labs were created when technology content was low and jointness was downplayed. A new model of defense innovation is now needed, one matched to today's strategies and problems.

Changes in Business Innovation

Making such a change may seem impossible, but a similar adjustment taking place in American business offers a model for the defense community. Leading corporations are embracing a hard-headed response to changing conditions of competition. In recent years, business innovation in the United States has shifted away from producing new things and toward process innovations and what we call retrofit innovation.[9] Businesses now recognize three regions in the innovation landscape: new products, new processes, and retrofits. These regions are like the topography of a map. They define distinct geographies that require different skills and search strategies. Just as an army trained to fight in the desert would not be effective in the mountains, technology institutions unfamiliar with the new geography of innovation will fare poorly in the marketplace.

General Electric

For decades, General Electric (GE) was an industrial company that manufactured a wide range of products: washers and dryers, medical imaging machines, jet engines, and steam turbines, to name a few. Today, GE sees itself as a service company, not a product company. It still makes many products, but it makes more profit from repairing, upgrading, and operating things that it and other companies have already made. There is a big sunk cost in products—millions of them are out there. Servicing these products is more profitable than turning out more of them.

At GE, innovation is much more about using technology to improve services than about investing in plants and equipment. GE has broadened its definition of return on investment to include how technology makes its sales and service workers more productive. Had the company continued to innovate by having its laboratories churn out an increasing number of better products, it would not be focusing on the high profit part of its business. GE recognized that the payoff from innovation varies with changing strategic conditions and that to stay competitive, they need to change, too. The U.S. defense community needs to learn this lesson. Unlike GE, DOD cannot afford to shift away from the development and insertion of new technologies; it must learn to navigate the whole spectrum of the technology landscape and choose which portion offers the most effective solution to a military need.

Wal-Mart

The Wal-Mart story is usually told as an example of how a company built a world-class logistic system. Let us look at this system from an innovation perspective.

Big retailers have historically succeeded by emphasizing product attributes, such as quality, displays, branding, and advertising. Wal-Mart chose a different path, for much the same reason that GE did. Competing on product attributes worked in the 1960s, but in the 1990s, when most households already owned more products than they knew what to do with and new products were flooding the market (and driving down profit margins), turning out better products did not yield the payoffs that it once did.

Wal-Mart chose to innovate in a different region by building a distribution system based on carefully synchronized routines and tightly coupled processes, all linked to logistics and marketing, and aligned with the corporate strategy of being the low-price, "big-box" retailer. Each night a stream of data is sent via satellite from every Wal-Mart store in the country to headquarters in Arkansas. This information is used to assign trucks from inventory depots to stores, determine the products they will carry, and quickly refill store shelves with what is hot at the moment. Wal-Mart has flexible floor displays designed to easily accept these shipments. They can shift counters instantly to display fast-selling items shipped overnight by truck. Inserting new goods into Wal-Mart stores is quick and cheap.

Because a significant part of Wal-Mart's inventory is in transit, rather than in the back rooms of stores, some 20 percent more floor space is available for selling inventory. In the low-margin retail business, this has big payoffs. Wal-Mart's process changes are best contrasted with its chief rival, Kmart, whose innovation system was the classic one of offering better products that the company hoped would catch the consumer's eye. It carried the innovation system that was successful in the 1960s into the 1990s and thus was playing the game the old way, throwing thousands of products at consumers and heavily advertising them. Trucking and IT systems were outsourced to a low-cost contractor with the justification that these were not Kmart's core competencies. As a result of its inertia and the process innovations of its competitor, Kmart was forced into bankruptcy in the 1990s.

Shifting innovation from products to services allowed many companies to keep pace with the altered competitive dynamics of the 1990s. It freed them to focus their creative energies on the problems that generated the most payoffs. By recognizing when to exploit the process or retrofit a product instead of investing in new product innovation, DOD could likewise realize significant benefits. This is especially true because many DOD needs are related to support or services. Innovation in retrofit or process support is as important to DOD as new product innovation.

Retrofit Innovations

The value of retrofits is evident in many different areas. National hardware chains like Home Depot and Lowe's now target the homeowner who wants to upgrade a home rather than buy a new one. The Baltimore Harbor development upgraded a crumbling old industrial neighborhood to a modern entertainment district. Airports are being refitted with security systems to protect against terrorists.

Hotel rooms are equipped for online gambling over the television, and JetBlue has retrofitted its Boeing 767 passenger jets with in-seat entertainment from DirectTV to transform the passenger experience in ways that caught its competition completely off guard.

Each of these innovations could be looked at as a new product or process. But looking at innovation this way misses the larger picture. Installing gambling in a hotel room is not a process or a product as much as it is a value upgrade of the room for the hotel owner. It leverages the costs of building, operating, and maintaining the room. The home improvement store, which makes a greater profit on the sale of upgrade materials than on hammers and nails, leverages the sunk costs of the homeowner.

One of the best ways to see retrofit innovation is in traffic congestion. American metropolitan areas are clogged with cars. There are two options for dealing with this problem: build more highways or increase the throughput of the existing system.

The first option involves constructing new freeways, widening existing roads, or double-decking bridges and freeways. This was the practice from the 1950s to the 1980s; with ample Federal funding, the gasoline tax, and the low cost of vacant land, road building seemed cheap.

By the 1980s, the costs of building new highways rose sharply. Actual construction expenses were only one part of the problem. Environmental, legal, and political obstacles also drove up the costs. Most important was the cost of inserting new capacity into the existing grid. By then, cities were surrounded by suburbs, and condemning homes and shops to install new highways had become prohibitively expensive. Imagine the cost of adding new traffic lanes to Interstate Route 95 between New York and Washington, DC. Whole neighborhoods of homes would have to be demolished. Double-decking Route 95 is feasible in an engineering sense, but probably not in an environmental or political sense. Key bottlenecks, such as the George Washington Bridge in New York, have already been double-decked. Adding a third deck would mean building a new bridge, at extraordinary cost.

An alternative to highway construction is to increase the throughput of the legacy system. Today, Route 95 is being retrofitted with a collection of automated toll collection systems; synchronized traffic signals; more responsive emergency vehicles to remove accidents; radio traffic alerts to warn drivers about congestion; and traffic cameras to spot tie-ups (and, someday, Internet notices to direct drivers around them). Each of these innovations can be considered a product or a process. But conceiving the problem this way misses a larger strategic change: an intelligent transportation system (ITS) is being retrofitted onto the legacy highway system.

The payoff from new highway construction has decreased. As the costs of new construction rise, retrofit innovation gives more bang for the buck.

Figure 3. Complexity and Sunk Costs

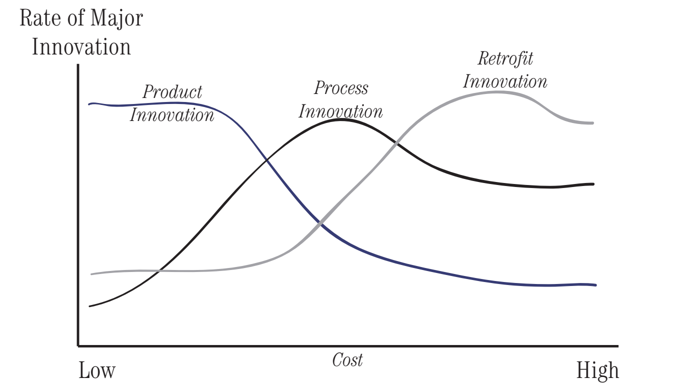


Figure 3 shows how innovations change as a function of complexity and sunk costs.[10] As those variables increase, innovation needs to shift first to better processes, and later, to retrofits.

The Defense Innovation Landscape

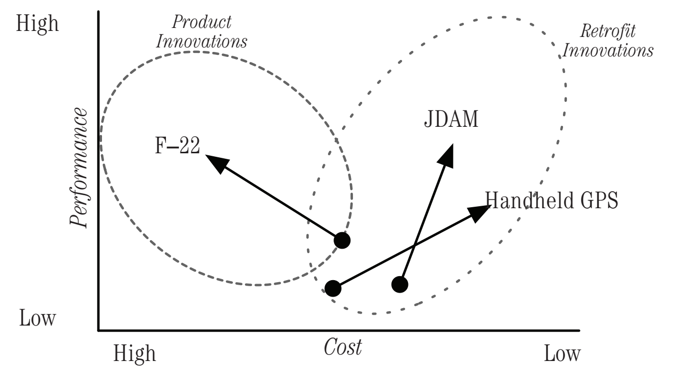
The defense innovation system is stuck in a mindset, albeit one that succeeded for half a century, that focuses on new products at the expense of processes and retrofits. The question is whether this same approach makes sense now. Defense contractors used to spend most of their time and energy on R&D and building weapons. Today, the majority of them do not do research and do not build anything. Rather they operate, maintain, support, and install complex technologies into a force already loaded with hardware. Yet the innovation institutions of the Cold War continue to perceive their mission as turning out better products. Operation and maintenance are seen as someone else's problem. Retrofits that exploit sunk costs are considered only in rare cases, and then not systematically.

People are trained for a world with low technology levels rather than for a world where making existing technologies work is the big challenge. For example, rather than writing new code, most computer programmers spend their time trying to figure out the programs someone else has written. They are not trained for this. It is just assumed that someone who reengineers old programs will need programming classes de novo.

For decades, DOD has purchased its IT systems from various vendors without giving enough attention to system interoperability. As a result, enormous amounts of effort have been expended on understanding how legacy systems fit with the new ones. Inserting a new IT system—the core of much current defense transformation—is a different kind of challenge than writing new code. It involves stitching together legacy systems, diagnosing faults, and checking for open loops.

The classic defense innovation pattern is shown on the left side of figure 4. The starting point of the arrow indicates the old system and the tip of the arrow the new, displayed on a cost-benefit diagram. The F–22 replaces the F–14. The cost of the F–22 is higher, but so is the performance. This is the kind of trade-off for which the current defense innovation system is built. It leverages technology against cost.

Figure 4. Emerging Innovation Patterns in Defense



But consider recent developments involving two innovations, the Joint Direct Attack Munition (JDAM) and the distribution of handheld global positioning system (GPS) receivers to Army and Special Operations forces. In the case of JDAMs, a guidance kit was retrofitted onto legacy gravity bombs. The JDAM leveraged the sunk cost in a large stockpile of "dumb" gravity bombs. GPS receivers similarly increased the performance of ground forces, yet were cheaper than the legacy system of beacons and radios the Army had been using.

There is no one best kind of innovation. The choice of approach depends on strategy and the relative costs of technology and performance. Sometimes historical circumstances determine which type of innovation works best. In the 1920s, for example, the German army, decimated in World War I, really had no choice but to rebuild from the ground up. Legacy hardware was not a problem because most of it had been captured or destroyed by the Allies. Force structure was limited by treaty. Historical studies have shown that these conditions pushed the German army to innovate in tank warfare.

The lesson usually drawn from the German interwar experience is that legacy systems need to be destroyed to make way for better weapons: German defeat in World War I removed bureaucratic obstacles, allowing the introduction of the tank. But this is the wrong lesson to draw. Disregarding the vast investment already made in legacy forces every time a new technology comes along would make no sense. Because of rapid product innovation, expensive and highly capable forces would have to be completely overhauled or replaced every few years. In a world of jointness and high interconnectivity, the result would be utter chaos.

Drawing conclusions about U.S. defense transformation in the 21st century from the German army in the 1920s overlooks some basic economics. Historical circumstance made the German transformation costs in the 1920s low. The U.S. Army today faces a fundamentally different set of conditions. It can barely keep up with the high technology content it already has.

Too often a political cast is given to this recurrent problem. For example, bureaucratic resistance is often cited as the biggest obstacle to innovation. Sometimes this is true, but not always. Bureaucratic forces may be the only ones correctly calculating the costs. What sometimes passes for bureaucratic opposition is often the failure of innovators to calculate the true costs of ownership. Their enthusiasm for new products blinds them to the economics of innovation.

Aligning Innovation with Strategy

America's defense innovation system needs to align itself with strategy and place greater emphasis on process innovations and the retrofit of legacy systems. The current system is so oriented to new production that it is choking the capacity to integrate these products into legacy forces. A visit to any ship, airbase, or Army training center shows this. People are overwhelmed by the complexity of recent hardware, the burden of IT systems that do not work as advertised, and the need to spend time on making things work at the expense of sharpening combat skills.

DOD controls an enormous asset that it usually overlooks when it considers innovation: the multi-trillion-dollar sunk cost in its forces. In the corporate world, firms often suffer from technological myopia, the tendency to stick with the technologies they know. A company with investments in resources and people is not likely to innovate outside of its comfort zone.[11] Firms stuck in old technologies stand to lose important competitive advantages if they change. Likewise, defense contractors prefer to stay with the technologies they know, because it is costly to switch, and they may not be as successful if they do so.

DOD's challenge is different. It does not share interests with the corporations that work for it and thus needs to see itself as a force for reshaping industry structure, getting firms to explore different regions of the innovation landscape. DOD should signal defense companies that it is going to consider all innovation alternatives to improve its fighting ability.

DOD has been rethinking its acquisition system, attempting to shift from the requirement of things to the acquisition of capabilities, and there are several ways to do this. It could offset the technological myopia of its contractors by signaling new opportunities to new entrants in the process and retrofit areas. Also, DOD could encourage all competitors to search the enlarged innovation landscape of figure 2. This would have the dual benefit of improving productivity where it is most needed and broadening the basis of defense competition away from domination by established firms whose innovations systems are geared to producing new products.

Market pressure drove GE and Wal-Mart to adapt new innovation strategies. Without it, there would have been no incentive to change. Market pressure for new kinds of defense innovation must come from DOD; otherwise, firms have little reason to change. A hands-off DOD policy on innovation, leaving it to the market, belies a fundamental misunderstanding of industrial economics. Absent incentives to change for DOD contractors, innovation system costs will only rise as defense transformation proceeds, because defense companies directly benefit from the high cost of operations, maintenance, and technology insertion. They know their own products best, so they win the O&M, insertion, and outsourcing work that goes with those products. The greater the complexity of this work, the more profits they earn. Why would they change voluntarily?

Several unique aspects of defense that are absent from private business also need to be recognized. Some defense innovations require emergency responses to unforeseen attacks and challenges, where the costs of failure are much higher than they would be in the private sector. Retrofit innovation can be especially important here. Integrating upgrades with legacy systems is often the fastest way to mount a serious defense. For example, in response to Soviet acquisition of nuclear weapons in the early 1950s, the United States retrofitted its World War II forces with nuclear punch. Nuclear weapons were put on bombers, aircraft carriers, and even on Army recoilless rifles like the Davy Crockett. If time were available, it would have made more sense to tailor specific weapons for the nuclear mission. But time was not available. The United States was in an emergency situation to defend the country and its North Atlantic Treaty Organization allies.

A similar logic applies to homeland security. A second terrorist strike on the United States of a magnitude comparable to 9/11 most likely would prompt a crash program to upgrade security at the Nation's air and sea ports. There probably would not be time to build new systems; instead, retrofitting existing systems would be required.

Conclusions

DOD's challenges are in many ways more complex than those faced in the private sector. It cannot change its core mission in the same way that private sector firms can. It can, however, become more agile and flexible in determining what range of solutions would best support its various needs. Becoming a more adept customer, one that drives the market, would enable the department to broaden its options and respond to changes in the strategic environment. A useful lesson to be learned from industry is that the synergies created from understanding and utilizing the landscape of innovation can provide more capabilities at equal or lower cost. America's innovation capacity is one of the greatest sources of its military advantage. To harness its potential, the defense innovation system needs to take account of some of the important changes that have taken place in the last decade.

Process and retrofit innovations are more important than they have been in the past. Yet many of the systems and rewards in place overlook this. Innovation needs to be aligned with strategy. Here, the interests of defense firms and DOD are different, and DOD has important responsibilities in aligning defense innovation to defense strategy

Notes

[1]See P. W. Singer's characterization of firms supporting the military in *Corporate Warriors: The Rise of the Privatized Military Industry* (Ithaca, NY: Cornell University Press, 2003), 136–148.

[2]"Sink or Swim: After Landing Huge Navy Pact, EDS Finds It Is In Over Its Head," *The Wall Street Journal*, April 6, 2004, A1.

[3]"Clumsy Response Hits RBC Brand," *The Financial Times,* June 16, 2004.

[4]See Richard Nelson, ed., *National Innovation Systems: A Comparative Analysis* (New York: Oxford University Press, 1993) and Michael Porter, *The Competitive Advantage of Nations* (New York: Free Press, 1990).

[5]Loren R. Graham, *The Ghost of the Executed Engineer: Technology and the Fall of the Soviet Union* (Cambridge: Harvard University Press, 1993).

[6]Martin Shubik, "Game Theory and Operations Research: Some Musings 50 Years Later," *Operations Research* 50 (January/February 2002): 1, 192–197.

[7]For a detailed description of the difficulties of applying the DOD's Planning, Programming, and Budgeting System (PPBS), developed along a model of planning in a successful 1950s industrial firm, to today's military, see Stuart Johnson, "A New PPBS to Advance Transformation," *Defense Horizons 32*, Center for Technology and National Security Policy (Washington, DC: National Defense University, September 2003).

[8]Lee Fleming and Olav Soreson, "Navigating the Technology Landscape of Innovation," *Sloan Management Review* (Winter 2003), 15–23.

[9]Retrofit innovation is a concept developed by Paul Bracken while working with large corporations and teaching a course on innovation strategies at Yale. It draws on Storm Cunningham, *The Restoration Economy* (New York: Barrett-Koehler, 2002).

[10]This chart is the authors' updating of James M. Utterback, *Mastering the Dynamics of Innovation* (Boston: Harvard Business School Press, 1996), 91. See also Cunningham, 30.

[11]Management theorists rediscover this problem every few years. It was originally put forth in Kenneth Arrow, "Economics, Welfare and the Allocation of Resources for Inventions," in *The Rate and Direction of Inventive Activity*, ed. Richard Nelson (Princeton: Princeton University Press, 1962).

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