volume 4 | issue 2 | spring 2009

A quarterly journal published by MIT Press

innovations

TECHNOLOGY | GOVERNANCE | GLOBALIZATION

Resilience
in a Turbulent World

ENTREPRENEURIAL SOLUTIONS TO GLOBAL CHALLENGES

innovations

TECHNOLOGY | GOVERNANCE | GLOBALIZATION

Lead Essays

Cases Authored by Innovators

Analysis

volume 4 | issue 2 | spring 2009

Perspectives on Policy

Organization of the Journal

Each issue of *Innovations* consists of four sections:

1. Lead essay. An authoritative figure addresses an issue relating to innovation, emphasizing interactions between technology and governance in a global context.

2. Cases authored by innovators. Case narratives of innovations are authored either by, or in collaboration with, the innovators themselves. Each includes discussion of motivations, challenges, strategies, outcomes, and unintended consequences. Following each case narrative, we present commentary by an academic discussant. The discussant highlights the aspects of the innovation that are analytically most interesting, have the most significant implications for policy, and/or best illustrate reciprocal relationships between technology and governance.

3. Analysis. Accessible, policy-relevant research articles emphasize links between practice and policy—alternately, micro and macro scales of analysis. The development of meaningful indicators of the impact of innovations is an area of editorial emphasis.

4. Perspectives on policy. Analyses of innovations by large scale public actors—national governments and transnational organizations—address both success and failure of policy, informed by both empirical evidence and the experience of policy innovators. The development of improved modes of governance to facilitate and support innovations is an area of editorial focus.

mitpressjournals.org/innovations
innovationsjournal.net

Peter Dombrowski and Eugene Gholz

Identifying Disruptive Innovation
Innovation Theory and the Defense Industry

Clayton Christensen developed a powerful framework for evaluating innovations and choosing business strategies to respond to technological change.[1] He divides innovations into two categories, "disruptive" and "sustaining," based mainly on whether or not the new product's performance is measured by new metrics. Sustaining innovations improve performance along an established trajectory that is familiar to traditional customers. Disruptive innovations, on the other hand, offer a different kind of performance that does not help traditional customers with their normal business practices. Christensen argues that incumbent firms will sensibly cater to their established customers, because they understand the established market well and work hard to preserve good customer relationships. As a result, incumbents will tend to focus on sustaining innovations and will neglect disruptive ones. However, this tendency will leave them vulnerable to new entrants that lack established customer ties and are therefore willing to pursue disruptive innovations, initially by selling to fringe customers. Christensen describes cases in a wide range of industries in which competition from new firms selling disruptive innovations led to the collapse of well-known, well-managed incumbent firms.

In this article, we improve on Christensen's theory in a way that makes it more analytically useful—making the theory more predictive than descriptive. Christensen actually defines disruptive innovations as those in which incumbent firms lose out in the post-innovation competition, conflating cause and effect. That choice helps make his case histories engaging and easy to read. But it also makes his theory hard to test and hard to apply *ex ante* rather than *ex post*, because it requires analysts to know the outcome of the post-innovation competition before they can assign the value of the independent variable—that is, before they can decide whether the innovation in question is disruptive or sustaining. Christensen also introduces auxiliary assumptions about the nature of competition in the product market that complicate the story. In this article, we remedy those problems, classifying innovations explicitly in terms of a single dimension

Peter Dombroski is a Professor at the Naval War College in Newport, R.I., where he is Chair of the Strategic Research Department.

Eugene Gholz is an Associate Professor at the LBJ School of Public Affairs at the University of Texas in Austin.

that is relatively measurable: the performance metrics that potential customers use to judge products.

Our improved classification of innovations depends only on the characteristics of the new product. Whether the product is a new device, a new organizational form, or some other kind of improvement, the question is whether the innovation improves performance that is measured in traditional ways or in new ways. Disruptive innovations offer new performance metrics, while sustaining innovations offer improvements along previously established performance trajectories.[2] Our adaptation makes it possible to empirically test Christensen's hypotheses: that incumbent firms are well positioned to produce sustaining innovations but rarely make disruptive innovations, and that disruptive innovations often allow new entrants to dethrone established market leaders. This improvement to the classification scheme for the independent variable makes Christensen's conceptual apparatus far more useful, and we hope that it offers a progressive step in the study of innovation.[3] We also illustrate our theoretical improvement with two case studies of contemporary innovation in the American defense industry.

In the 1990s, American political and military leaders watched the world change: computers and communications innovations revolutionized all areas of civilian and commercial life. Generals, admirals, and civilians in the Office of the Secretary of Defense grew anxious. When they had entered military service decades earlier, most took pride in military equipment that was at the cutting edge of technology. But as the World Wide Web, cellular telephones, and Playstations beckoned from the civilian world, military technologies increasingly looked obsolete. By the late 1990s, most military leaders were committed to applying comparable information technology to military tasks. According to transformation proponents, the new investment in high-tech equipment is more important than ever, because transformation should improve military efficiency and effectiveness in the "global war on terror."

Many military leaders claim that the information technology "revolution in military affairs" should also involve replacing the established defense industry. They have observed that entrepreneurial upstarts often replaced established firms during the commercial information technology revolution. Perhaps those same upstarts should also invade the military market: if Cisco Systems makes vital networking equipment for Wal-Mart, perhaps Cisco can and should make similar equipment for the military. Even if commercial equipment cannot be used directly in the military context, and even if commercial IT firms cannot easily develop separate product lines to sell to the military, it seems reasonable to replace the established defense firms. Today's defense industry, which grew up during the Cold War, is skilled in developing and manufacturing non-networked, traditional military equipment. For the Information Age, the argument goes, the United States military needs a new group of dynamic suppliers, replete with information technology specialists and new core competencies.[4]

As intellectual support for the idea that the military should buy its equipment from new suppliers, advocates of transformation like Vice Admiral Arthur

Cebrowski, who headed the Pentagon's Office of Force Transformation after he retired from the Navy, openly borrowed from Christensen's celebrated approach to business analysis. In explaining revolutions in military affairs, military analysts have generally emphasized how new technologies change the ways that militaries organize and fight, often upending the balance of power among leading nation-states. That is, analysts emphasize the effects of innovation on military power but they take the innovations themselves as *sui generis*.[5] By reaching out to consider the sources of innovation and the ways that industry helps to implement new military ideas, transformation advocates tapped into one of the most dynamic research fields in business analysis, economics, sociology, and engineering.[6] Unfortunately, Cebrowski's fortuitous encounter with Christiansen's theory led to a faulty analysis of the challenges facing the U.S. military and its equipment suppliers. Transformation advocates, misinterpreting the theory in part because of the weaknesses in Christensen's initial description, often exaggerate the likely amount of turmoil in the industrial landscape of the defense industry.

In particular, Cebrowski and others latched onto Christiansen's concept of disruptive innovation, but their use of the term has less to do with the substance of Christensen's analysis than its convenience as an evocative shorthand for vast technological, organizational, and cultural changes. Transformation clearly will entail big changes for the military that will certainly disrupt established routines, and big change is naturally described as "disruptive" in casual conversation.

But disruptive innovation in Christensen's sense has a technical meaning that does not capture the actual situation that military planners face when they seek to procure innovative technologies. As we will demonstrate, what the military actually wants from its transformation project generally fits the technical definition of sustaining innovation. And according to Christensen's logic, that means that the best source of supply for the new equipment is the established defense industry. So transformation advocates made a mistake when they tried to steer military purchases to new firms. This mistake had real implications for business and the defense budget, but the American political process helped correct it.

DISRUPTIVE AND SUSTAINING INNOVATION

Reducing Christensen's concept to its essence, the definition of a disruptive innovation is a technological change that introduces a product whose performance is measured in new ways. A disruptive innovation will also perform *worse* than the established market leader when measured according to traditional quality standards.[7] Established firms' strategic planning departments tend to recognize that inferior performance and to reject proposals to invest in a disruptive innovation; their evaluation is reinforced by feedback from their best customers, who benefit from the product's performance measured in traditional ways.[8] According to Christensen, disruptive innovations can only flourish when they are managed by nontraditional organizations, that are not locked into particular customer relationships. The nontraditional suppliers can find customers in fringe market niches, where the product's performance is measured according to new metrics. Only a new firm (or a new, truly independently managed division of an established firm) would have the incentive and the flexible organizational culture to establish relationships with customers interested in the new performance metrics and to develop the technical and financial expertise to evaluate research proposals in light of the new technological trajectory.

Building on experience gained in the fringe market, the manufacturer producing a successful disruptive product can sometimes improve its performance even when it is measured using traditional performance standards, so it can eventually satisfy even the customers of the established market-leading product—the ones who originally rejected the disruptive innovation. In those cases, the upstart manufacturer will often drive the established suppliers out of mainstream markets.[9]

Of course, if an established firm's strategic planners could predict the rapid improvement in the disruptive product's performance, then the established firm would happily invest in the new technology despite its initial inferiority. Unfortunately, it is especially difficult to predict improvements based upon previously unrecognized product attributes.[10] Business strategists fear that new technologies will develop into "bad performers" in the long run, rather than becoming revolutionary products that fundamentally change the market.[11] As Christensen points out, it often seems like a reasonable decision for an established firm to kill a disruptive innovation.

Christensen contrasts disruptive innovations with sustaining innovations, that build on familiar product-quality metrics, making improvements "along the dimensions of performance that mainstream customers in major markets have historically valued."[12] Sustaining innovations, no matter how complex, technically radical, or resource intensive, rarely drive established firms out of business; instead, they tend to reinforce their success. Expert technical and financial advisors in established firms predict that sustaining innovations will prove feasible, and they understand how to update business plans to capitalize on the new technology. Mainstream customers promise that they are willing to pay a premium for the performance improvement. Hence, the established firms take the steps they need to develop sustaining innovations. Customers and suppliers can cooperate on systems definition and engineering to develop the new products.[13]

To summarize, Christensen introduced a new classification that describes some innovations as disruptive and others as sustaining, which at its core depends on whether the innovation relies on new or traditional performance metrics.[14] He then makes two theoretical claims about disruptive innovations: (1) market-leading firms are unlikely to invest in them; and (2) under some conditions, new suppliers that first sell disruptive innovations in fringe markets will drive the established suppliers out of mainstream markets, too. In his various writings, Christensen offers some evidence to support each of these theories. To facilitate our analysis, we must clarify the difference between the *definition* of disruptive innovations and Christensen's *theories* about the effects of disruptive innovation.

Without this clarification, even the best-intentioned attempt to work with Christensen's classification of innovations is fraught with difficulty; our clarification also highlights two ways the theories can be improved. Although Christensen's core concept is very useful as it urges us to think about whether performance metrics change, some of his key assumptions about customer-supplier relationships do not always apply—notably in the military context, but also in other business areas where customer demand "pulls" innovation and where prices are not necessarily the key determinant of purchasing decisions.

First, Christensen assumes that inventors start with a technological idea and then try to find a customer who is willing to buy the product they have invented. Here the challenge is to escape the familiar customer relationship—in which the customer will not want the disruptive product because it performs poorly on traditional lines—and to find a new customer willing to buy.[15] However, sometimes it is a customer rather than a supplier who makes the conceptual breakthrough that drives innovation. When that happens, the challenge is to explain the idea to producers rather than to find a profitable use for the new technology. If the idea builds on familiar performance metrics, the explanation process is likely to proceed smoothly and the supplier will readily build the new product. However, if the customer's idea requires a change in performance metrics—that is, if it is an idea for a disruptive innovation, then the customer is likely to find it hard to work with the established supplier. Military transformation is a case of such demand-driven innovation.

Second, Christensen assumes that disruptive innovations always enter the market at a low-cost, low-quality price point. That is, they "are so much more affordable to own and simpler to use that they enable a whole new population of people to begin owning and using the product" or "they were simply low-cost business models that grew by picking off the least attractive of the established firms' customers."[16] These possibilities come from the simplifying assumption that a product can be completely described by its cost and its performance measured along a single dimension: that customers and suppliers constantly make simple cost-performance trade-offs in designing and buying systems.

But customers actually make purchasing decisions using many metrics in addition to price: they seek the best value for their money, and they often judge product quality along several dimensions.[17] If the old state-of-the-art product had several desirable attributes, a disruptive innovation might introduce a new performance metric but at the same time reduce performance on one or more established metrics and leave the final cost exactly the same. For example, a disruptive innovation might add wireless capability to an existing widget while increasing its size and reducing its speed. Even though the new product might sell for the same price as the previous one, established users would reject the innovation because its performance would fall short on size and speed; only the new, "fringe" wireless consumers would want the product. But we have no reason to believe that the new performance metric will only interest the fringe at an especially low price. Those customers were previously unable to buy a wireless product at any price. As long as the new performance metric attracts users who want to apply the innovation to do something that the established users would not have wanted to try, Christensen's disruptive innovation dynamics should apply: the new product will only sell to new customers, and if those new customers did not exist, then the established customers would have killed the product development through their contacts with the established firm's marketing and strategic planning departments.

The military context illustrates this point clearly. Most transformational systems for the military are not the low-cost, low-quality products that Christensen assumes will result from disruptive innovation; they are high-end innovations. But because the military is not a particularly price-sensitive customer, the failure of innovations to reduce unit costs is not necessarily a barrier to their widespread adoption.[18] The question is whether the transformational military equipment will introduce new performance metrics at the same time it reduces quality measured in traditional ways (in which case transformation would call for disruptive innovation). The alternative is that transformational military equipment will simply require improvements along well-known technological trajectories of such magnitude that soldiers, sailors, and airmen can use the innovative equipment in new, Information Age ways.

The bottom line here is that we can extend Christensen's main theoretical insight beyond the limits of his initial analysis. The core of the theory depends on dividing innovations into two categories based on how customers measure their performance. Some innovations (sustaining ones) improve product performance based on familiar metrics, and established firms almost always make those sustaining products and sell them through established customer-supplier relationships. Other innovations (disruptive ones) introduce new performance metrics, and they sometimes require new channels linking customers and suppliers. New channels frequently mean that new firms enter the industry and replace the established producers, but that process will not necessarily involve new producers finding new customers for the disruptive product. Instead, established customers sometimes pull the disruptive innovation along. In that case, the customers may find new suppliers to whom they can explain their idea for a disruptive innovation, but they may also choose to continue working with familiar suppliers because they still value some of the old, established performance metrics as well as the new one.

INNOVATION IN THE DEFENSE MARKET

Using this more precise version of Christensen's key terms, we can decide whether military transformation advocates' casual view of the future defense industry logically follows from their beliefs about the nature of future warfare. For many contemporary military analysts, it seems obvious that the ways that nation-states fight and prepare for war should change if global society undergoes a revolution in technology and organization. Dominant military capabilities should always derive from the leading industries of the age.[19] Famous futurists like Alvin and Heidi Toffler have often been quoted to this effect: "A military revolution, in its fullest sense, occurs only when a new civilization arises to challenge the old, when an entire society transforms itself, forcing its armed forces to change at every level simultaneously—from technology and culture to organization, strategy, tactics, training, doctrine, and logistics."[20] So in the post-modern age, military doctrine should follow the best practices of the emerging information society—conceptual, organizational, and technological.

For transformation advocates in the late 1990s and early 2000s, the problem was less convincing the rest of the military that a Brave New World was at hand than determining how information technologies should be adapted to warfare. Network-centric warfare doctrine emerged from their intellectual struggle.[21]

Networks harness the power of geographically dispersed nodes (whether personal computers, delivery trucks, or warships) by linking them together into networks (such as the World Wide Web) that allow for the extremely rapid, high-volume transmission of digitized data (probably multimedia data). Networking has the potential to increase exponentially the capabilities of individual nodes or groups of nodes and to facilitate the efficient use of resources. When networked, an individual node gains access not only to its own capabilities but also, more importantly, to capabilities distributed across the network. For example, a reconnaissance sensor can be small and stealthy because it does not need to carry its own weapons to act on the information it discovers; the sensor will just pass the data into the network, where a separate shooter node can determine that it has the best shot among the friendly forces in the area, maximizing the chance of success in an efficient, precision engagement. Moreover, in a robust network, the loss of a single node need not be crippling, because other nodes can assume the functions of those that are damaged or destroyed. In sum, military units of all types will be able to share information through communications links that will allow, among other things, more precise targeting, faster operations, and a smoother flow of materiel through the logistics pipeline.

This concept of future warfare has profound implications for equipment design—the implications that intuitively seem like a call for disruptive innovation. Since networked nodes can share information efficiently, they can be designed as simple, low-cost adjuncts to the network itself. Ideally, network-centric warfare will feature smaller, lighter, faster, less complex, and less expensive nodes that will present adversaries with fewer high-value targets. Network-centric platforms may include small warships, new satellites, unmanned vehicles for intelligence gathering or for launching attacks on highly defended targets, and a host of other platforms. In each case, complexity is to reside in the network rather than in the node.

MILITARY INNOVATION IN SPECIFIC PRODUCTS

A close look shows that military transformation generally calls for new products that conform better to the definition of sustaining innovation than to the definition of disruptive innovation. Thus, contrary to the conventional wisdom in defense circles, careful analysis implies that the established defense industry is well positioned to supply the next generation of military equipment. Led by firms like Boeing, General Dynamics, Lockheed Martin, Northrop Grumman, and Raytheon, in one market niche after another, the defense industrial base will at most need to blend old and new performance metrics. In most parts of the industry, the old performance metrics will prove more important than the new ones in responding to the military's quest for transformation. Subcontractors and joint venture partners may contribute disruptive innovations, but the systems integration prime contractors—those that interface with the military customer—will continue to perform the same key tasks that they have for decades. The military plans to use the innovative weapon systems to fight in new ways, but fundamentally those new ways of fighting will capitalize on improvement along established performance trajectories.

Case studies on small ships and military communications systems—two types of military equipment widely thought to be strongly affected by transformation—show that advocates of transformation were largely incorrect in their early suppositions that the military should seek a new group of equipment suppliers.[22] Once the major defense contractors figured out what network-centric warfare was all about, they responded quickly and aggressively. In the following paragraphs we demonstrate how the military demand for disruptive and sustaining innovations affects the prospects of both traditional and nontraditional suppliers competing in the shipbuilding and communications sectors.

Small Ships

By emphasizing the need for smaller, lighter, and faster nodes, network-centric warfare challenges the Navy to reverse several generations of ship designs that favored larger, massively complex, multipurpose ships. Theorists argued that the Navy should buy smaller, single-purpose ships that rely on information technology to call on other platforms in the network when they need additional functionality. The Navy's acquisition plan for the Littoral Combat Ship (LCS) was meant to implement this aspect of transformation.

The established shipyards have repeatedly demonstrated their ability to build the old style of high-end ships. Their core competencies allow them to perform the complex integration of subsystems within relatively large hulls. For example, the hulls of the *Arleigh Burke* destroyers are roughly the size of traditional cruisers' hulls.[23] Individual ships of that class are intended to fight antisubmarine and anti-air warfare battles at the same time they prepare for (and perhaps execute) land attack/strike missions. Thus the *Arleigh Burke* design bristles with antennas, carries many types of missiles, and squeezes an enormous amount of equipment into a confined space. The designs of aircraft carriers, amphibious ships, attack submarines, and even combat-support ships reflect the same core competencies in naval architecture and complex craftsmanship that make the *Arleigh Burke*–class ships tremendously capable.

The new Littoral Combat Ships are quite different from the Cold War destroyer design. Their hulls can accommodate the hardware and software required for any of several mission modules (e.g., one for mine warfare missions, one for protection against small boat attacks, etc.), but they can only fit one module at a time, and the modules can only be changed in port. So, on a given deployment, an LCS is optimized for only one task rather than the *Arleigh Burke*'s multi-role outfitting. An LCS hull is just big enough to accommodate the mission module, a relatively small crew, and the supplies and equipment necessary to sail across the open ocean on an extended deployment. The U.S. Navy's official description of the LCS program stresses that it will build "network-centric" ships and contrasts the LCS to traditional multi-mission ships. The description also emphasizes that the LCS will be maneuverable, stealthy, and, most of all, relatively small.[24]

Whether these new design characteristics require disruptive innovation from the shipbuilding sector depends on how they affect key performance metrics. Single-purpose ships should generally require less space for their mission systems, because they require less functionality. Even though the Navy is buying a ship that is significantly smaller than its traditional multi-role platforms, the LCS ship designers had the opportunity to expand the space allocated to its single-purpose mission systems. The naval architecture task was actually simpler, because designers did not have to make room simultaneously for equipment for other tasks. Thus the old measure of ship quality—the ability to fit many complex systems into a single hull—has become somewhat less relevant. Instead, the LCS emphasizes a different performance metric, the ship's interoperability with the Navy's combat network.

Because of this changing emphasis, it is no surprise that nontraditional suppliers took on major roles in developing and producing the Littoral Combat Ships. The nontraditional yards (Marinette Marine, Bollinger Shipyards, and Austal USA) have not invested in complex naval architecture as a core competency, so they may have a long-term advantage in design competitions that reduce that complexity.

On the other hand, other aspects of LCS development reinforced the role of traditional military-oriented shipyards. Throughout the extended development process, the Navy's doctrine writers pressed to make the new ships much smaller than legacy ships, because smaller ships tend to be stealthier, faster, and cheaper. The emphasis on small size was also consistent with the new-economy theme of miniaturization. Consequently, the ratio of mission-system size and complexity to hull size did not change as much as it might have. This pressure preserved some of the value of the traditional shipyards' naval architecture skills. Meanwhile, other aspects of the LCS effort tracked directly with established performance metrics: the ever-increasing emphasis on electronics, smooth integration of high-tech weapons modules, and reliance on high-speed, robust, secure communications integration with the other ships deployed in the same battle group. Military-oriented shipyards understand these metrics very well, but the smaller shipyards, historically oriented toward simpler, domestic, commercial production, have not tried to apply them in the past. Overall, the shift to single-purpose ships called for a lot of sustaining—rather than disruptive—innovation.

The result for the LCS program was that the Navy actually worked with two of its established suppliers (Bath Ironworks, owned by General Dynamics, and Lockheed Martin), each of which was deeply involved in the design and construction of the *Arleigh Burke* class. Those traditional prime contractors each partnered with a non-traditional shipbuilder to build the ships' hulls: Marinette Marine and Austal are relatively small shipyards that have not sold major combatants to the Navy in the past. The Navy is getting its transformational small ships while drawing on very advanced expertise in naval architecture, military electronics, and systems integration.

Most major defense acquisition efforts—indeed, most major civilian government projects and even private-sector developments—run into various problems, including initial deliveries that are behind schedule or over budget, and that perform short of the initial rosy hopes.[25] Despite, or perhaps because of, the LCS partnerships between traditional prime contractors and small shipbuilders, the first several vessels were no exception.[26] To date, the Navy has commissioned one LCS, and another has been launched but remains under construction. Because of the program's troubles, though, the Navy actually cancelled orders for five more Littoral Combat Ships in 2008.[27] But in early 2009, Secretary of Defense Robert Gates strongly endorsed the program, regardless of its problems, as part of his sweeping plan to revamp defense procurement. In May 2009, the Navy awarded new contracts for the third and fourth LCS ships (one each to the teams led by General Dynamics and Lockheed Martin), and current plans call for a total of 55 Littoral Combat Ships.[28] Not surprisingly, this higher number would help the Navy reach its headline goal of 313 ships and will satisfy key legislators and their constituencies.[29] The Navy can mobilize its network of traditional suppliers and other political support precisely because key elements of the LCS program demand sustaining innovation. It should not be a surprise how much the LCS program looks like a traditional Navy acquisition effort.

Military Communications

Network-centric warfare is meant to improve military effectiveness by replacing existing military communications with a new approach. Point-to-point, single-purpose communications systems with limited capacity and flexibility will be replaced by high-volume systems meant to share data widely and quickly. Many proponents of network-centric warfare believe that it will require more changes in military communications than in any other area of technology.

In the caricature of the military's current communications systems, all aspects of making a connection are hardwired into each piece of communications equipment, from physical characteristics like radio frequency to the list of digital messages that can be sent to convey information. That tight integration allowed designers to tailor the systems to perform specific tasks. Each warfighting community had different jobs to do, and each one got a highly capable, customized solution to its communications problems. But those self-contained designs hamper interoperability between systems and prevent modern battle management systems from combining data from multiple sources in real time to achieve the best possible view of the battle space.

The existing systems also pose other problems for transformation to network-centric warfare. Many legacy systems are optimized for voice communications rather than for transmitting data. And they were not designed to dynamically allocate connections to units entering or leaving the battle space, or to relay messages automatically among nodes to get around terrain obstacles, jamming, or other service interruptions. In sum, legacy communications systems were designed for discrete tasks across specific, planned connections. They were not designed as "networks," and they most certainly were not designed to handle the volume of data and the number of nodes envisioned by transformation advocates. The profound change to network-oriented designs certainly *seems* like an example of disruptive innovation.

But despite the demanding requirements that transformation poses for scientists and engineers in the communications sector, the technological trajectory is actually familiar. One of the key things that military commanders want from new communications technology is more data throughput—a well-known measure of a system's performance. During the course of the Cold War, transmission efficiency improved. Old communications systems tied up a frequency whether or not they were sending any real data. The next step in improving efficiency, embodied in currently deployed systems, arranged for groups of radios to talk to each other by taking turns using the same frequency. Such systems are based on a library of allowed messages that can each be transmitted during a standard time slot, and each radio in the system, one after the other, is allocated a time slot in which it has the opportunity to send a message to all the others. These legacy systems have great difficulty dynamically allocating time slots to new participants in the network, and their data transmission rates slow down as more participants enter the network. Also, they cannot send large volumes of data efficiently because they are constrained by the predetermined duration of each time slot. In sum, the current communications systems are certainly not optimized for efficient transmission. But the currently deployed radios were an important step forward compared to what came before, and that step shows that it is hardly a new idea to improve communications by making data flow more efficiently.

The military's next generation of communications gear, the Joint Tactical Radio System (JTRS), is expected to improve performance on this metric by a substantial margin.[30] The internal workings of the JTRS are based on the now-familiar transmission technology of the Internet. Instead of taking turns sending messages, JTRS users will pump packets of data onto the network whenever they have something to send. Each radio that receives a packet will be able to tell whether the packet needs to be sent on further through the network; once a packet reaches its destination, it will be combined with other packets into a complete message. Under this system, users do not need to wait their turn to send messages, nor do they need to wait for an entire cycle through the network before they can send additional packets of a multi-packet message. Each JTRS box will include an "intelligent router" to help manage the network's data transmission load. Ideally, packets will be sent through connections that have room for them, avoiding traffic jams.

JTRS requires a major change in networking technology, which might even be described as a "radical" innovation for defense suppliers familiar with the old military communications style. As a result, developing the new technology for JTRS demands a considerable investment of resources. Boeing, the prime contractor for the first wave of JTRS radios, struggled to stay on schedule and within its cost targets and at one point was asked to "show cause" why its contract should not be terminated. After a major program restructuring, Boeing continues to lead a team making one type of the new radios (for ground forces), while other traditional defense suppliers are leading the efforts to make radios for use in aircraft and ships, radios to be carried by special forces soldiers, and radios for other uses.

The key insight is that new technology for military communications mostly requires sustaining innovation.[31] As long as the demand is for improvements along established performance metrics, the established suppliers will more likely be able to pull off the innovation than any nontraditional supplier would be. Trying to expand bandwidth, improve transmission efficiency, and, ultimately, increase data throughput is nothing new for defense communications suppliers. The JTRS program never called on nontraditional suppliers as prime contractors, so we cannot directly compare the performance of nontraditional to traditional suppliers. But looking carefully at the history of the program, Boeing's problems seem to reflect the normal challenges of pursuing radical innovation.

No one should expect every radical innovation effort to succeed, even if it is an effort to produce a sustaining innovation. Moreover, just because JTRS is over budget and behind schedule does not yet mean that the new radios will not significantly improve the military's ability to execute network-centric operations. Boeing may yet pull this off—or JTRS may yet fail.[32] But neither the evidence from the program nor the analysis of the type of innovation the JTRS requirements call for suggests that the traditional supplier is struggling because the program really calls for disruptive innovation.

INVESTING IN SUSTAINING INNOVATION: IS IT WORTHWHILE?

To some readers, this story of sustaining innovation in the defense industry may seem disappointing. Many business analysts, including Christensen, fear that only disruptive innovation can truly generate excitement and big profits for investors.[33] Military transformation sounds like it should bring a major change in the business landscape, and with major change firms can expect important opportunities to make money—if they accept a significant risk of failure. But if military transformation is mostly about sustaining innovation, then where is the opportunity for substantial business growth?

Fortunately, there is little risk of death by ennui. Sustaining innovations can earn profits, because they are more useful to customers than the old state-of-the-art equipment, and customers will be willing to pay for the better product. In the case of military transformation, even if the defense industry's post-9/11 boom of sales to support ongoing military operations slows over time, the industry will still grow, as long as military transformation remains a goal of the Obama Administration. Secretary of Defense Robert Gates has repeatedly warned the services to focus on the current wars in Afghanistan and Iraq rather than fall victim to "Next-War-itis."[34] Secretary Gates has already announced cuts to funding for several major programs that some transformation advocates had favored. On the other hand, his plans have helped other programs, such as the Littoral Combat Ship. In this uncertain business environment, defense firms (and their government customers) need to be resilient by "anticipating, managing and responding to sudden change."[35] Understanding the meaning and implications of disruptive and sustaining technologies can provide needed resilience in the defense sector.

The fear that investors will internalize the expectation of sustaining innovation and fail to reward it with substantial growth assumes that the size of the market for sustaining innovations is fixed and foreseeable. Military transformation is a good example of the impossibility of perfect foresight. The customer, through a political process, decided to spend significant resources beyond the normal defense budget, intending to drive the pace of sustaining innovation. The idea of a "military Internet" suddenly appealed to politicians and generals alike. Investors who had put their money into the defense business before that political commitment earned an unexpended boom due to a surge in spending for sustaining innovation.

Is that growth potential as exciting as taking a start-up company with a disruptive innovation from nothing to market dominance? Of course not. One of the crucial lessons of this analysis is that investors should not confuse a defense firm with a commercial information technology company: defense firms are not "dot coms." Defense firms are more like regulated utilities. They sell to a huge customer whose purse strings are controlled by politicians in Congress rather than by finance experts, venture capitalists, and institutional investor shareholders. If defense firm profits get too high for politicians, they launch investigations, uncover scandals, and pass laws to take back "excess profits." On the other hand, defense companies are protected from crushing market downturns: even when the military wants to cut back on its equipment purchases, pork barrel politics kick in to preserve employment in key factories, cushioning the shock with steady, low-rate production contracts that also preserve corporate profits.[36] The sustaining innovations called for by military transformation are simply another step in the evolution—and growth—of this particular utility sector.

Close analysis does not support the oft-expressed view that military transformation requires a new stable of suppliers. Military discussions are filled with military-specific terms of art, but military leaders and defense analysts have been very casual with the phrase "disruptive innovation" that they borrowed from business theory. Unfortunately, the technical definitions of sustaining and disruptive innovation are particularly easy to abuse—as Christensen and Raynor lament in a footnote in *The Innovator's Solution*.[37]

Because little of the demand for innovative military systems to implement network-centric warfare requires disruptive innovation, the acquisition of the next generation of military equipment, applying information and communications technology to solve national security problems, will not replace the established defense industrial base with new firms. Instead, new entrants into defense markets will sometimes sell or license innovative processes and technologies to established defense firms. This is good news for the executives, employees, and shareholders of Boeing, General Dynamics, Lockheed Martin, Northrop Grumman, Raytheon, and the other established prime contractors. It is also good news for companies with innovative components that will be useful as part of military transformation: while the non-traditional suppliers will not replace established players, they will also not have to bear as many of the extra costs associated with the government's convoluted acquisition regulations (another area in which established defense suppliers excel).

Those apostles of transformation who believe that the revolution in military affairs should import a sweeping change in the industrial landscape from the civilian economy's shift to the Information Age should carefully re-examine the detailed performance metrics required for new military systems. Business case analysis often relies on intuitive insight, but it is not easy to tell the difference between sustaining and disruptive innovation with a quick glance. As a result, the widely accepted view of the future of the military-industrial complex is wrong.

Our cases offer important lessons for scholars examining the firm-level sources of innovation. First, the terms disruptive and sustaining innovation have been applied far too casually to diverse technologies and industrial sectors. Our emphasis on the core of the concept—whether an innovation relies on a new performance metric or progress along established lines—helps to make Christensen's theory more analytically useful. Moreover, we can broaden the range of industries where this method of analysis can be helpful if we jettison some of Christensen's auxiliary hypotheses and assumptions; for example, his assumption that disruptive innovations always enter the market at a low price point. Sometimes consumers rather than producers come up with a new idea, and sometimes an invention introduces a new performance metric without lowering the product's price. Even in those circumstances, though, analysts can use Christensen's core framework to predict whether a new product is likely to be sold through familiar customer-supplier connections or whether new relationships need to develop (new suppliers, new buyers, or both).

---

1 Clayton M. Christensen, *The Innovator's Dilemma: When New Technologies Cause Great Firms to Fail* (Boston: Harvard Business School Press, 1997); Clayton M. Christensen and M. E. Raynor, *The Innovator's Solution: Creating and Sustaining Successful Growth* (Boston: Harvard Business School Press, 2003).

2. Other scholars are also thinking about ways to make the term "disruptiveness" more analyt-

ically useful. For example, Vijay Govindarajan and Praveen Kopalle surveyed senior executives in many different firms and introduced a quantitative scale of disruptiveness based closely on Christensen's original definition. They showed that disruptiveness differs from previously established classifications of innovations such as "radical" or "competency-destroying." We analyze a particular industry in depth, better illustrating how the concept of disruption, when clearly defined, can be used to make predictions about industry-level outcomes, and also illustrating in detail the perils of casual, less-systematic analysis of sustaining and disruptive innovations. Vijay Govindarajan and Praveen K. Kopalle, "Disruptiveness of Innovations: Measurement and an Assessment of Reliability and Validity," *Strategic Management Journal*, 27 (2006), pp. 189-99.

3. Imre Lakatos, "Falsification and the Methodology of Scientific Research Programmes." In I. Lakatos and A. Musgrave (eds.), *Criticism and the Growth of Knowledge* (Cambridge: Cambridge University Press, 1970), pp. 91-196.
4. Arthur K. Cebrowski and John J. Garstka, "Network-Centric Warfare: Its Origin and its Future," U.S. Naval Institute *Proceedings*, 124 (1998), pp. 28-35.
5. Andrew Krepinevich, "Cavalry to Computer: The Pattern of Military Revolutions," *The National Interest*, 37 (1994), pp. 30-43; Martin van Creveld, *The Transformation of War* (New York: Free Press, 1991); Thomas G. Mahnken, *Technology and the American Way of War since 1945* (New York: Columbia University Press, 2008).
6. E. Cefis and O. Marsili, "A Matter of Life and Death: Innovation and Firm Survival," *Industrial and Corporate Change*, 14 (2005), pp. 1167-92; H. Sornn-Friese, "Frontiers of Research in Industrial Dynamics and National Systems of Innovation," *Industry and Innovation*, 7 (2000), pp. 1-13.
7. Christensen (1997), p. xv; Govindarajan and Kopalle (2006), pp. 190-91; R. Adner, "When Are Technologies Disruptive? A Demand-Based View of the Emergence of Competition," *Strategic Management Journal*, 23 (2002), pp. 667-88; Clayton M. Christensen, Jerome H. Grossman, and Jason Hwan, *The Innovator's Prescription: A Disruptive Solution for Health Care* (New York: McGraw-Hill, 2008), pp. 5-6.
8. Alternatively, strategic planners may force the disruptive technology into a traditional line of business, where it is destined to fail in the marketplace. See Christensen and Raynor (2003), pp. 103-7, 109-17, 190, 194.
9. Christensen (1997), p. 189. At various points, Christensen implies that this level of success—driving established suppliers out of mainstream markets—is part of the definition of a disruptive innovation. That version of the definition has been widely accepted by other scholars, including Adner (2002) and Govindarajan and Kopalle (2006). As Erwin Danneels (2004, p. 250) has noted, if this level of success is part of the definition of a disruptive innovation, the concept is extremely difficult to use *ex ante.* It also makes Christensen's theory of innovation extremely hard to test, because analysts cannot identify "failed" disruptive innovations. Simplifying the definition of a disruptive innovation to our preferred wording, "a technology that introduces a new performance metric and performs less well than the prior art when measured by an established performance metric," still dovetails with Christensen's explanation that incumbent firms often fail to invest in the disruptive technology because of their ties to mainstream customers. But unlike Christensen's formulation, the simplified definition can be measured *ex ante*. And then some of these disruptive innovations will succeed in overthrowing the pre-existing industrial landscape, while others will simply turn out to be "failed" innovations that lose money. Alternatively, a disruptive innovation may succeed in a parallel market segment yet have no effect on the original market dominated by the traditional supplier. The result of this re-formulation is that, like Christensen, we predict that almost all disruptive innovations will be developed by non-traditional suppliers, but we do not require that all disruptive innovations lead to the bankruptcy of incumbent, traditional

suppliers. For related arguments, see Erwin Danneels, "Disruptive Technology Reconsidered: A Critique and Research Agenda," *Journal of Product Innovation Management*, 21 (2004), pp. 246-58; Constantinos Markides, "Disruptive Innovation: In Need of Better Theory," *Journal of Product Innovation Management,* 23 (2006), p. 21.

10. Rebecca Henderson, "The Innovator's Dilemma as a Problem of Organizational Competence," *Journal of Product Innovation Management*, 23 (2006), pp. 7, 9.
11. Harvey M. Sapolsky, "On the Theory of Military Innovation," *Breakthroughs,* 9(1), (Spring 2000), p. 39; Adner (2002), p. 667.
12. Christensen (1997), p. xv.
13. Eric von Hippel, *The Sources of Innovation* (New York: Oxford University Press, 1988).
14. Christensen might not accept the clarification proposed in this article, but even so, he has been very clear in his own writings that he draws a distinction between the descriptive parts of his writings and what he calls "normative theory." In a 2006 article, he implies at least twice that driving incumbent suppliers out of business is not a necessary characteristic of a disruptive innovation. Unfortunately, though, he also introduces yet another new version of the definition of a disruptive innovation—different from those he used in Christensen (1997), and Christensen and Raynor (2003). Rather than following that moving target, we prefer to look for analytical leverage using a clear, simple definition of the concept based on performance metrics. See Clayton M. Christensen, "The Ongoing Process of Building a Theory of Disruption," *Journal of Product Innovation Management,* 23 (2006), pp. 39-55, esp. pp. 45, 48-49.
15. Adner (2002), p. 670.
16. Christensen and Raynor (2003), pp. 45, 46. Surprisingly, this assumption is shared by both subcategories of disruptive innovations that Christensen and Raynor discussed in T*he Innovator's Solution*, "new-market" and "low-end" disruptions.
17. Daneels (2004), p. 249.
18. Jacques S. Gansler, *Affording Defense* (Cambridge: MIT Press, 1991), pp. 141-214.
19. William H. McNeill, *The Pursuit of Power: Technology, Armed Force, and Society since A.D. 1000* (Chicago: The University of Chicago Press, 1982).
20. Alvin Toffler and Heidi Toffler, *War and Anti-War: Survival at the Dawn of the 21st Century* (Boston: Little, Brown and Company, 1993), p. 32.
21. For one account of the intellectual battles see Peter Singer, *Wired for War: The Robotics Revolution and Conflict in the Twenty-first Century* (New York: Penguin Press, 2009), pp. 179-204.
22. Earlier, more detailed versions of these case studies were published in Peter Dombrowski and Eugene Gholz, *Buying Military Transformation: Technological Innovation and the Defense Industry* (New York: Columbia University Press, 2006).
23. David T. Burbach, Marc Devore, Harvey M. Sapolsky, and Stephen Van Evera, "Weighing the U.S. Navy," *Defense and Security Analysis*, 17(3) (December 2001), pp. 259–265.
24. See http://peoships.crane.navy.mil/lcs/program.htm, accessed on July 31, 2008; see also Steve Liewer, "First Littoral Combat Ship Begins Sea Trials," *San Diego Union-Tribune*, July 29, 2008.
25. Some of the problems, of course, should be attributed to overly optimistic plans rather than failures in project execution. Harvey M. Sapolsky, Eugene Gholz, and Caitlin Talmadge, U.S. Defense Politics: The Origins of Security Policy (London: Routledge, 2009), pp. 81-95.
26. Peter Dombrowski and Andrew L. Ross, "The Revolution in Military Affairs, Transformation and the Defense Industry," *Security Challenges*, 4(4) (2009), pp. 13-38, esp. pp. 32-33.
27. Ronald O'Rourke, "Navy Littoral Combat Ship (LCS) Program: Background, Oversight Issues, and Options for Congress," *Congressional Research Service Report* (updated November 2008), p. 8.
28. Andrea Shalal-Esa, "Update 3—Littoral Ship Deals on Right Cost Trend—U.S. Navy," Reuters, May 7, 2009.
29. "Witnesses Question Navy's Ability To Reach 300-Ship Fleet, Throw Support Behind LCS," *Defense Daily*, March 27, 2009.
30. Thomas K. Adams, *The Army After Next: The First Postindustrial Army* (Palo Alto: Stanford

University Press, 2008), p. 90.

31. JTRS requirements call for ad hoc allocation of network slots. For example, a missile flying across the battle space should be able to join the network temporarily without planning and programming a specific network connection in advance. That ad hoc capability does introduce a new performance metric to the defense world, an element of disruptive innovation; however, in the context of military demand for improvement on multiple performance trajectories, most of which are sustaining innovations, on balance JTRS best fits the definition of a sustaining innovation.
32. As usual, the military program managers assigned to the project maintain an optimistic assessment of their prospects. Scott R Gourley, "JTRS JPEO Update: From 'On the Rocks' To 'On the Air,'" *Army* (May 2008), p. 65.
33. Christensen and Raynor (2003), pp. 1-9.
34. Robert Gates, U.S. Secretary of Defense, speech delivered at National Defense University, Washington, DC, September 29, 2008, www.defenselink.mil/speeches/speech.aspx?speechid=1279. Downloaded May 20, 2009.
35. Philip Auerswald and Debra van Opstal, "Coping with Turbulence: The Resilience Imperative," *Innovations: Technology, Governance, Globalization,* Special Idition for the annual meeting of the World Economic Forum (2009), p. 204.
36. Eugene Gholz and Harvey M. Sapolsky, "Restructuring the U.S. Defense Industry," *International Security*, 24 (1999-2000), pp. 5-51.
37. Christensen and Raynor (2003), p. 66.