

## About the Author

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## Key Points

- ◆ Historically, the Department of Defense (DOD) has relied on strategic forecasting to determine specifications for new military products. These specifications are codified in formal product requirements that drive new product development (NPD).
- ◆ The rapid rate of technology change combined with increasing uncertainty in the global security environment challenges the ability of DOD to make accurate long-term predictions about future military product needs.
- ◆ To improve the efficacy of capability development, many DOD agencies and the Defense Industrial Base are exploring NPD strategies based on the insights of lead users with direct exposure to emerging military-technology problems.
- ◆ This paper details emerging approaches to military NPD that incorporate lead users; that is, practitioners who experience and proactively solve needs ahead of the market.

# The Pentagon's Pivot: How Lead Users Are Transforming Defense Product Development

by Adam Jay Harrison

Prior to America's entry into World War II, President Franklin D. Roosevelt coined the term *Arsenal of Democracy* to refer to U.S. industrial activity supporting the Allied war effort.<sup>1</sup> President Dwight D. Eisenhower subsequently named the collection of private firms, universities, and Federally funded research and development centers that emerged during the World War II the military-industrial complex. The industry component of the military-industrial complex, or what is now commonly known as the Defense Industrial Base (DIB), has grown to become one of the largest sectors of the U.S. economy, accounting for nearly 4 percent of gross domestic product—a substantially greater percentage if the impact of military-derived technology such as the Internet is included in the calculation.<sup>2</sup>

The modern DIB reached its apex in the Cold War. During this period, massive weapon systems development programs led the Department of Defense (DOD) to evolve a complex, heavily managed, deliberate approach to new product development (NPD). Confronted with an adversary in the Soviet Union that mirrored a centralized, planning-centric NPD model, the DIB successfully built sophisticated military products that had a decisive role in determining the outcome of the Cold War.

Today, however, the national security environment is characterized by increasingly diverse, reactive threats that can evolve at the pace of Moore's Law, a concept that refers to the doubling of transistors in a dense integrated circuit every 2 years.<sup>3</sup> One example of the reactive threat phenomenon is improvised explosive devices (IEDs). Constructed from commercially derived components, IEDs began appearing on the battlefields of Iraq and Afghanistan as early as

2002, where they have been responsible for most U.S. combat fatalities.<sup>4</sup> It is generally accepted that the main challenges in mitigating the effect of IEDs are their lack of standardization combined with a NPD cycle that measures in weeks to months. At the height of the fighting in Iraq, new IED variants began appearing on the battlefield nearly coincident with the deployment of U.S. countermeasures to the previous generation threat.

Within this context, DOD and its primary industry suppliers have started to actively explore alternate NPD models that promise to accelerate the development of military products in line with the accelerated evolution of threats and associated military product demand. While the defense market today continues to be driven by a multiyear formal planning cycle, the companies comprising the DIB, ranging from agile startups

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to the “big six” defense contractors (Lockheed Martin, Boeing, Northrup Grumman, General Dynamics, Raytheon, and BAE Systems), are experimenting with new NPD approaches that incorporate the real-time insights of military practitioners into novel product concepts. Leveraging lead users (that is, practitioners who address experienced needs ahead of the market), the DIB seeks to capitalize on early demand signals that anticipate scalable military needs.

## Lead User Innovation

Eric von Hippel, professor of Management of Technology at the Massachusetts Institute of Technology, defined *lead users* as those whose “present strong needs that will become general in a marketplace months or years in the future.”<sup>5</sup> Such users represent two principal opportu-

nities for firms pursuing NPD strategies that anticipate general market demand. First, lead users are a source of market research based on their exposure to experienced needs ahead of most users. Second, lead users are a source of product improvements and new product concepts, arising from their attempts to satisfy these needs.

Unlike conventional market-led approaches to NPD, which may be constrained by the experience of most users regarding felt needs and potential solutions, lead user innovation discounts prevailing products and applications in favor of emerging niche needs and associated product and process concepts. Per von Hippel, lead users express attributes applicable to the identification of emerging market opportunities to the extent that they face needs before the bulk of the marketplace experiences them and “are positioned to benefit significantly by obtaining a solution to those needs.”<sup>6</sup> This characteristic makes lead users a source of market research particularly in fast-moving fields such as high technology, where the experience of most users may be obsolete due to what Everett Rogers and later Geoffrey Moore identified as the uneven rate of technology diffusion.<sup>7</sup> In markets such as information and communications technology (ICT), the rate of product innovation may be less than the time required for an innovation to be communicated to most potential users. Rogers models the diffusion of innovations in a regular distribution based on the speed of adoption, where groups of users are classified from most innovative to most conservative as “innovators,” “early adopters,” “early majority,” “late majority,” and “laggards.” Lead users are assigned to the first segment of the user population (that is, “innovators”), which accounts for a small fraction (2.5 percent) of the total user population but plays a critical role in driving the process of technology diffusion. Therefore, a firm’s ability to identify the needs experienced by lead users and the self-generated solutions invented to address these needs can provide what Lieberman and Montgomery defined as a technological leadership-based first-mover advantage.<sup>8</sup>

In addition to the market research function, lead users may also serve as the agents of minimum viable

product (MVP) development. Ries defined a *minimum viable product* as a “product with just enough features to gather validated learning about the product and its continued development,” undertaken to satisfy the unmet needs experienced by the user.<sup>9</sup> Von Hippel postulated that the greater the perceived benefit that the user can derive from a solution, the more effort the user will expend to obtain or invent a solution. Moreover, the users likely to perceive the most benefit from a solution are those who will devote the most time to understanding the application domain.<sup>10</sup> Due to their deep technical experience and motivation to form solutions in domains where they are deeply invested, lead users are a potentially rich source of innovation. Firms capitalizing on this behavior may incorporate lead user MVPs to jumpstart or otherwise de-risk NPD.

In scenarios where the cost of knowledge transfer from lead users to firms may be high, lead users can play an increasingly important role in driving NPD. Von Hippel characterized information that is costly to acquire, transfer, and use in a new location as “sticky.”<sup>11</sup> Sticky information exists in many contexts, however, a prominent example is the “learning by using” scenario, which is a heuristic process that as Rosenberg concluded, “involves problem solving carried out in the use environment by, typically, product users.”<sup>12</sup> Polanyi observed that some knowledge earned in praxis is difficult to “encode in explicit terms.”<sup>13</sup> Such tacit information may be difficult or impossible to transfer. One strategy for firms seeking to capitalize on sticky or tacit information in NPD involves shifting NPD development activities to lead user locations, where lead users can directly participate in the development of prototypes or MVPs. Here, prototypes serve as artifacts that encode and transfer sticky information.

Domain expertise, early exposure to needs potentially indicative of broader market trends, and motivation to develop technology interventions addressing experienced needs make lead users increasingly important resources in NPD, particularly in areas where the rate of technology change is high. As DOD and the DIB seek

to accelerate military NPD in line with the increasing speed and reactivity of the national security environment, lead user innovation stands out as one potential solution. For this reason, DOD and the defense industry have begun to explore a variety of mechanisms to incorporate lead user input into NPD. In the following sections, I describe how the DIB traditionally executes NPD and explain how lead user innovation is being incorporated into military NPD through a variety of different government and industry-led initiatives.

## The Defense Industrial Base and New Product Development

No nation is more representative of the modern military-industrial complex than the United States. Shaped during World War II and tempered in the Cold War, the American military-industrial complex is an extreme example of a co-evolutionary economic model built in response to two existential global conflicts but sustained and even reinforced by internal pressures ranging from economic interests to regulatory conditions and cultural predispositions, to name a few.

The DIB is a collection of private companies, universities, and Federally-funded research and development centers (FFRDCs) that provide products and services for the U.S. Armed Forces. Companies that comprise this group, including the six largest defense contractors, are partially if not entirely underwritten by public military spending. Defense prime contractors produce equipment that is generally not available in the commercial marketplace. The DIB, however, also incorporates firms like Kraft Foods, United Parcel Service, and Amazon Web Services, whose sale of goods and services to the military constitutes a small fraction of their total addressable market.<sup>14</sup> Per Watts, the commercial-facing firms represented in the DIB traditionally do not produce critical components or systems required to “ensure DOD’s competitive advantage in the core military competitions.”<sup>15</sup>

The closed, reciprocal relationship between the American military and its industrial base is predicated

first and foremost on the sustainment of military-technology superiority. In World War II the competitive advantage enjoyed by the U.S. military was based on industrial output, and the American Soldier fought with machines bearing the names of great commercial firms such as Ford, General Electric, and General Motors.<sup>16</sup> In the Cold War, however, a different set of geostrategic realities demanding a new industrial strategy confronted the United States. The Soviet Union and its satellites maintained a two- to five-times numerical advantage over the United States and its Allies in most categories of conventional forces. This numerical asymmetry led U.S. military strategists to adopt what came to be known as

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the technology offset strategy, which sought to counter or “offset” Soviet military mass using increasingly sophisticated, force-multiplying weapons systems. More than any other factor, the offset strategy shaped the development of the military-industrial complex in the West.<sup>17</sup>

The insatiable demand for advanced technology implicit in Western military strategy eventually resulted in a gap between civilian and military markets. Where, in the early days of the Cold War, commercial firms in the West sought to leverage military investments for the development of products applicable to more scalable civilian markets, military-technology specialization eventually led to a near complete exit of legacy commercial firms from the business of defense and a failure to attract new firms with primarily commercial market aspirations. Per Gansler, the residual firms persisting in the military market were a collection of predominantly Federally-funded companies, laboratories, and nonprofit organiza-

tions exclusively optimized to produce technologies and systems for the military.<sup>18</sup> This group of public and private institutions is most commonly associated with the modern DIB.

With the segregation of commercial firms from the military marketplace, the military-industrial complex evolved increasingly complex business rules and regulatory frameworks antithetical to commercial industry norms. Practices common in the military-industrial complex such as cost-type accounting and government-use rights for intellectual property represented significant transactional barriers to firms for which the military was a secondary market. Thus, over the four-plus decades of the Cold War, the military-industrial complex grew somewhat independently of civilian high-tech industry punctuated by a few notable exceptions, like the Internet and the Global Positioning System, where technology “spill-over” from the military laid the groundwork for new civilian-use products.

Over the course of the Cold War due to the exit of dual-use firms from the defense market, the residual U.S. defense industry internalized business practices consistent with a monopsony centered on DOD. From a product development standpoint, the evolution of the DIB away from the dynamics of the commercial marketplace has had profound implications. Like any large bureaucracy, DOD has implemented complex business rules that support the development and deployment of new products and services at scale. The strict formalism of product development is further exacerbated by the context of national security where a conservative military culture presides and product decisions may have life or death implications. In toto, these factors have combined to produce a byzantine NPD model composed of three overlapping business systems that the Defense Science Board has criticized as favoring predictability and reliability over responsiveness and accuracy (that is, product-market fit).<sup>19</sup>

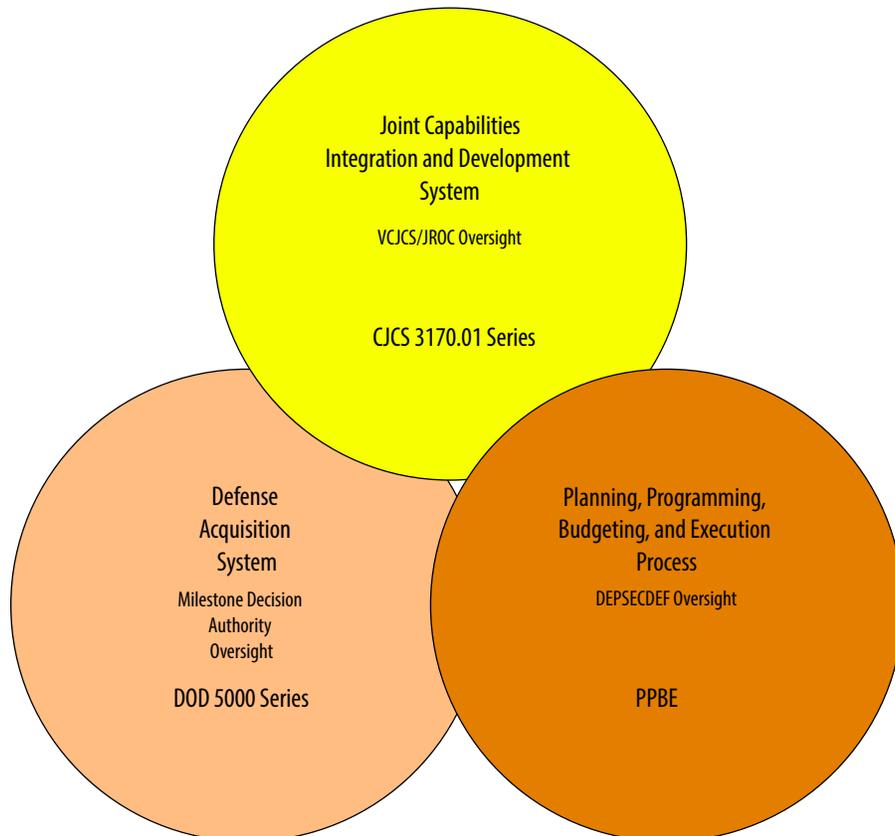
The three business systems associated with defense NPD combine to address the entire product development life cycle, from design and development to obsoles-

cence management. These business systems include the Joint Capabilities Integration and Development System (JCIDS), which manages the development of requirements (product specifications) that reflect future military capability needs; the Planning, Programming, Budgeting, and Execution (PPBE) process, which allocates resources for product development activities; and the Defense Acquisition System (DAS), which manages the government-to-industry contractual transactions governing NPD.<sup>20</sup> These three systems, referred to collectively as the Defense Acquisition Enterprise (figure 1), impose a prescribed order over military NPD as instantiated in artifacts like the Federal Acquisition Regulation System, which codifies contracting rules and consists of approximately 180,000 pages of regulation.<sup>21</sup> Simply initiating military NPD can take years to accomplish, requiring the development of policy like the national defense strategy as well as program-specific analyses reflected in Capabil-

ities-Based Assessments and Initial Capabilities Documents, each subject to a rigorous approval process.

Given the significant constraints of the DOD NPD model along with the increasing sophistication of modern military weapons systems, it is not surprising, as Lorell and Levaux noted, that more military aircraft designs were developed in the 1950s than the following four decades combined and nearly 70 percent of all post-World War II jet fighter development programs took place between the end of the war and 1961.<sup>22</sup> The bureaucracies that have evolved in parallel with the increased complexity have also become a major check on innovation and NPD. Today, hundreds of thousands of people are employed by the many government agencies that make up the Defense Acquisition Enterprise. The roles, missions, and functions of these agencies are optimized to the unique business requirements of the legacy NPD model. The internal reference to the existing business systems at the expense of external, market-driven

**Figure 1. Department of Defense Decision Support System**



factors has led to a myopic focus on process. Bureaucratic inertia and workforce incentives consign military NPD to what Baghai, Coley, and White identified as Horizon 1-type innovation, which refers to managing mature product development processes and product categories at the expense of new, potentially disruptive (that is, Horizon 3) products that are not predicted by the established model.<sup>23</sup> The resulting dissonance between traditional military NPD and the rapidly emerging needs of military users has influenced the DIB and some government agencies to start exploring alternate NPD approaches based on lead user innovation.

## Lead Users and Military Product Development

Following the invasion of Afghanistan in late 2001, U.S. and coalition forces began experiencing the deadly effects of IEDs. Constructed from repurposed consumer

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electronics and (initially) Soviet-era munitions, remotely triggered, vehicle-based, and victim-triggered IEDs have claimed the lives of more than 3,100 U.S. military personnel and wounded more than 33,000, accounting for up to two-thirds of U.S. combat-related casualties in Afghanistan and Iraq. Current research suggests that the full extent of IED-related injuries is only now being discovered with military personnel suffering from late onset traumatic brain injury and post-traumatic stress disorder numbering many times original casualty estimates.<sup>24</sup>

The upsurge in IED incidents beginning in 2003 laid bare the inadequacy of existing military wheeled ve-

hicles like the ubiquitous High Mobility Multipurpose Wheeled Vehicle, or “Humvee,” to withstand an IED attack. The problem gained widespread public notoriety in December of 2004, when a Tennessee National Guardsman told then Secretary of Defense Donald Rumsfeld during a visit to a U.S. military base in Kuwait that troops had been reduced to foraging for scrap metal to weld to their vehicles for added protection.<sup>25</sup> This incident led in part to a massive response on the part of DOD. Zoroya estimated that to date the Defense Department has invested some \$75 billion in armored vehicles and technologies for detecting and defeating IEDs since the onset of the threat.<sup>26</sup>

Despite the massive investment in IED countermeasures, U.S. military efforts to mitigate the deadly effect of IEDs at the point of attack can only be considered modestly successful. Higginbotham documented the “cat and mouse” nature of IED innovation starting first with the development of remotely controlled, radio frequency-activated IEDs appearing in 2003, followed by the emergence of IEDs triggered by the engine heat of passing vehicles in 2004, decoy-proof IEDs in 2006, and finally IEDs triggered by the emissions of radio-controlled IED “jammers” in 2010.<sup>27</sup> In each case, the evolutionary leap came in response to a U.S. countermeasure that undermined the efficacy of the preceding generation of IED.

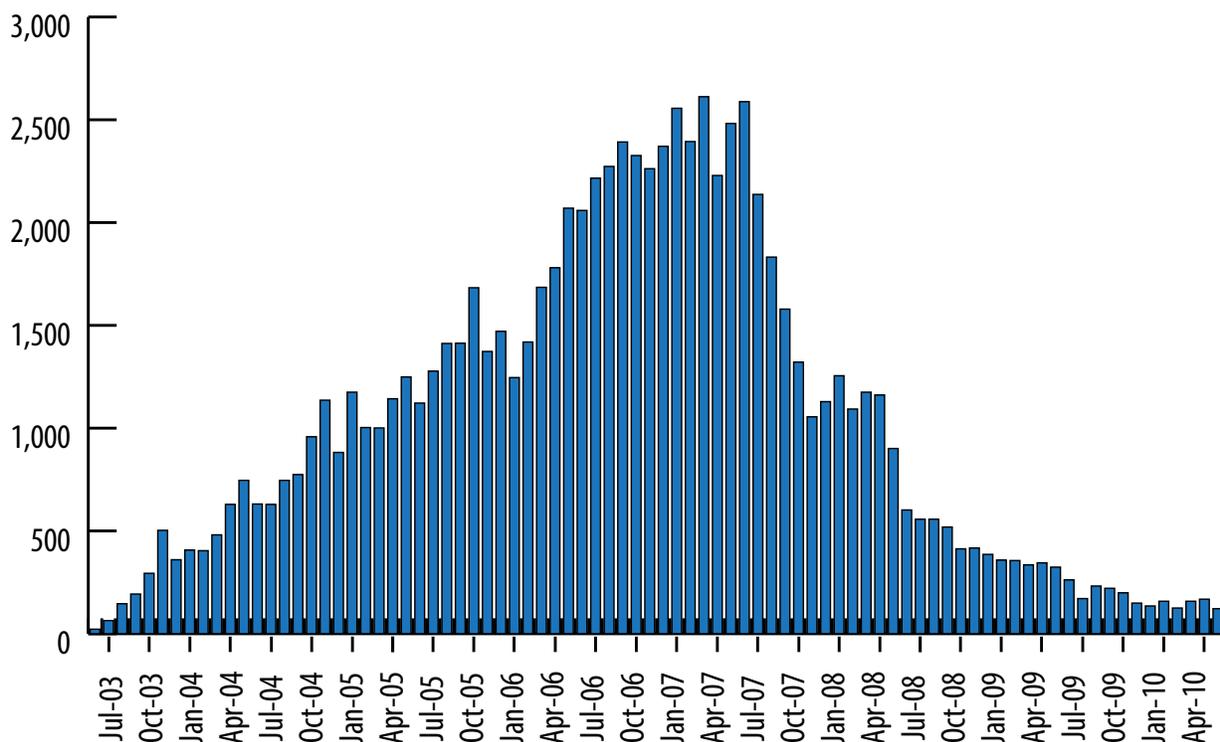
Given the lethality and strategic effect of the threat on popular support for military operations in Afghanistan and Iraq, countering IEDs emerged as a focus for DOD research and development in the early years of both conflicts. Regardless, IED-based incidents rose dramatically between 2003 and 2007. In addition to the dramatic overall increase in the number of IED incidents reported by Cordesman, Loi, and Kocharlakota for the 2003–2007 period, data suggest another interesting phenomenon—regular, short-term cycles of IED activity (figure 2).<sup>28</sup> Colonel Pete Newell, USA (Ret.), former director of the Army Rapid Equipping Force, attributed the waxing and waning of IED incidents over 2- to 6-month periods in part to the rapid IED innova-

tion cycle, where the deployment of new U.S. countermeasures initially reduced the number of IED incidents for a short period of time. The down-cycle was followed closely by an increase in the number of incidents associated with the implementation of new IED variants and employment techniques immune to U.S. countermeasures. Importantly, the timescale associated with the IED innovation cycle was inconsistent with the decades-long military NPD model—an asymmetry that resulted in the selective proliferation of lead user innovation based approaches to counter new IED variants.

Within the context of DOD, military personnel in direct contact with the threat environment are an important lead user group. In the case of the DOD experience with IEDs in Afghanistan and Iraq from 2003–2013, lead users consisted of Soldiers, Marines, Sailors, and Airmen engaged in combat and combat support operations. Several cases from this timeframe are indicative of how military personnel confronted with the emergence of IEDs expressed lead user characteristics. For example,

wheeled vehicles supplied by U.S. forces in Afghanistan and Iraq in the 2001–2004 timeframe were not equipped with blast mitigating armor.<sup>29</sup> As the exchange between the National Guardsman and Secretary of Defense Donald Rumsfeld underscores, frontline military personnel were ahead of the military market and most military users in experiencing and recognizing the need to improve armor protection on wheeled vehicles like the HMMWV. Because of their vulnerability to the devastating effects of IEDs, these lead users would disproportionately benefit from potential solutions. Thus, military lead users in Afghanistan and Iraq were among the first to experiment with improvised vehicle armor based on reinforcing “thin-skinned” vehicles with whatever was available including scrap metal, Kevlar blankets, ballistic glass, and even plywood.<sup>30</sup> While subsequent experience would reveal that these field expedient solutions (that is, minimum viable products) had a more palliative than practical effect on improving the survivability of wheeled vehicles, feedback from early lead user experimentation

**Figure 2. Total IED Incidents, June 2003–April 2010**



became an important factor in the design of follow-on “applique” or add-on armor packages.

As late as February 2006, DOD was still in the process of retrofitting wheeled vehicles in Afghanistan and Iraq with basic add-on armor protection. From 2003, when the upsurge in IED incidents began, to 2006, when the deployment of baseline “up-armored” vehicles to U.S. military personnel was nearing saturation, insurgents in Afghanistan and Iraq introduced multiple generations of new IED threats including Explosively Formed Penetrators designed to overcome add-on armor, jammer-proof bombs that use a vehicle’s heat signature as a trigger, and decoy-proof targeting designed to overcome pre-detonation schemes.<sup>31</sup> To the extent that the emergence of new

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IED threats outpaced the diffusion of countermeasures, military lead users would continue to play an important role in driving counter-IED NPD. For example, when insurgents introduced IEDs triggered by heat signatures in response to the U.S. military’s introduction of radio-controlled IED jamming devices, military lead users improvised a contraption consisting of a hot metal box (for example, a toaster heating element) affixed to the end of a long pole extending in front of the vehicle. The heat signature emanating from the metal box served to detonate a heat-triggered IED ahead of the vehicle.<sup>32</sup> This solution became the basis for a new military product called the Rhino, which was widely distributed to U.S. forces in Afghanistan and Iraq.

IEDs are but one example of the accelerated rate of change in the threat environment driven by what Schwab refers to as the fourth industrial revolution—the acceleration of innovation due to ubiquitous information exchange and the emergence of cyber-physical systems like cloud computing and the Internet of Things.<sup>33</sup> To keep pace with the development of new threats and the demand from military personnel for solutions to mitigate these threats, DOD agencies and the DIB alike are at least tentatively internalizing the lessons of the IED experience in several lead user innovation programs. Two prominent examples of how lead user innovation is influencing military NPD are the U.S. Army Rapid Equipping Force (REF) and the Joint Improvised Threat Defeat Organization (JIDO).

Both the REF, which was established in 2002, and JIDO, which was established in 2006, were chartered with operating outside of the traditional Defense Acquisition Enterprise and capitalizing on lead user insights to quickly address the emerging needs of U.S. military personnel. These organizations have developed processes that allow for insights from the field to be collected, analyzed, and actioned through rapid NPD that incorporates prototyping and experimentation. The REF has implemented a streamlined process called the “10-liner” to solicit inputs from military lead users and initiate NPD. For fiscal year 2014, the REF collected 554 10-liners leading to the delivery of 6,472 new or nonstandard products in an average of 140 days from identification of need to product delivery (REF 2015). In addition to lead user information push, the REF and JIDO deploy liaisons and field teams to pull sticky information relevant to NPD by working alongside lead users in real-world problem-solving environments. Knowledge derived from such interactions provides a basis for new product specifications that drive prototyping activities in DOD labs and industry.

DOD agencies are also engaging military lead users to participate directly in the conceptualization, design, and prototyping of new products. In 2013, the REF initiated a pilot program called Army CoCreate, which con-

nected military lead users with scientists, engineers, and development resources to accelerate NPD. The program was based on the crowdsourcing and web-enabled co-development of product concepts incorporating inputs from military lead users. NPD activities were facilitated by an Internet-based CoCreate platform and followed by ideation and prototyping events called Make-a-Thons, where product concepts were refined and built.<sup>34</sup> More recently, the Marine Corps deputy commandant of Installation and Logistics, in partnership with the MD5 National Security Technology Accelerator, initiated an Innovation Challenge program to collect lead user concepts to improve logistics. The first Innovation Challenge was launched on June 15, 2016, and focused on lead user concepts in the advanced manufacturing and Internet of Things technology areas.<sup>35</sup> Selected winners from the challenge will be prototyped by DOD laboratory and DIB partners and circulated back to the lead user community for experimentation.

The U.S. Special Operations Command (USSOCOM) is another early adopter of lead user innovation techniques in military NPD. Long familiar with rapid product development to support the diverse, unconventional missions of the special operations community, USSOCOM has embarked on two recent efforts to incorporate lead users into the formal acquisition process for NPD. In the case of one high visibility program called the Tactical Assault Light Operator Suit (TALOS), or “Iron Man” suit, the Special Operations Forces (SOF) Acquisition, Technology, and Logistics (AT&L) organization has assigned top special forces personnel with recent combat experience to the TALOS acquisition team. One technique employed by the TALOS program involves using lead user feedback to frame capability challenges that are then socialized with industry. Potential solutions resulting from initial outreach to the DIB are subsequently refined through collaborative product design sessions involving both lead users and industry.<sup>36</sup> Based on experience with the TALOS program, SOF AT&L has launched a new initiative called SOFWERX to expand opportunities for lead user collaboration with

innovators in government, academia, and industry. SOFWERX consists of a collaboration space and associated programming such as Warfighter Council Wednesdays, where Active-duty special operators discuss needs and potential solution concepts.

As DOD agencies have moved toward lead user innovation to enhance NPD, the DIB has followed suit. A company called Local Motors stands out as a leader in developing the methodologies and tools required for DOD to capitalize on lead user innovation. As the industry partner behind the Army CoCreate program, Local Motors built the online platform used to facilitate co-development of a mobile command post vehicle based on inputs from military lead users and civilian innovators.<sup>37</sup> Army CoCreate derived its origins from a

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2011 effort undertaken by Local Motors in partnership with the Defense Advanced Research Projects Agency (DARPA) called the Fast, Adaptable, Next-Generation Ground Vehicle (FANG). In this program, Local Motors and DARPA demonstrated techniques for crowdsourcing military vehicle design from lead users representing a variety of fields and competencies. The result was an Experimental Crowd-derived Combat-support Vehicle built in less than 4 months.<sup>38</sup>

Large defense contractors have also started to take note of lead user innovation as a method to accelerate and improve NPD. Opened in 2005, the Lockheed Martin Center for Innovation (also known as The Light-house), uses virtual and live collaboration to involve

military lead users in activities that inform independent research and development and anticipate scalable military NPD opportunities. Taking a slightly different tact, General Dynamics has created what they call the EDGE Innovation Network—a government, university, industry collaboration network that connects technology to lead user-identified needs.

While lead user innovation is becoming an important tool for military NPD, capitalizing on the full potential of lead users in the development of military products will not be possible until these approaches are reconciled with DOD's legacy NPD business systems. Current instances of lead user innovation in the military context tend to be associated with applied research and development activities, where technology prototyping is prevalent. A very small percentage of DOD research and development programs, however, successfully transition to scalable military products, a phenomenon that is referred to as the valley of death. An effort working to apply lead user techniques to scalable military products is Tactical Advancements for the Next Generation (TANG). Leveraged primarily by the Navy, TANG uses design thinking (that is, a methodology that matches people's and organizations' needs with what is technologically feasible) to capture lead user insight, which may aid in the optimization of large product programs.<sup>39</sup> To date, the TANG methodology has been used in product areas ranging from undersea surveillance to food services.

## Conclusion

As the DOD grapples for product-based solutions that keep pace with the rapid rate of change in the modern operational and technology environments, lead user innovation is emerging as an important element of military NPD. By incorporating the insights of lead users, DOD agencies and the DIB gain early exposure to the needs and product opportunities that will drive future demand—a critical factor in accelerating the timeliness and efficacy of military capabilities. Given the formalism surrounding military NPD, however, fully capitalizing on lead user innovation involves crafting strategies that

relate lead user inputs to the business systems that govern NPD. Such an outcome relies first and foremost on successfully consolidating lead user feedback in the development of requirements for new military capabilities via JCIDS and associated Service-led combat development and force modernization processes. Expansion of programs like TANG, which reconcile lead users to the acquisition phase of military NPD, are also necessary to ensure that work-in-process capabilities reflect emerging opportunities and threats.

## Notes

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<sup>2</sup> Robert Levinson, Sopen Shah, and Paige K. Connor, "Impact of Defense Spending: A State-by-State Analysis," *Bloomberg Government* (November 2011), available at <[www.ct.gov/ecd/lib/ecd/futures/6.\\_bloomberg\\_defense\\_spending.pdf](http://www.ct.gov/ecd/lib/ecd/futures/6._bloomberg_defense_spending.pdf)>.

<sup>3</sup> Gordon Moore, "Cramming More Components onto Integrated Circuits" *Proceedings of the IEEE* 86, no. 1 (1965), 82–85.

<sup>4</sup> Anthony H. Cordesman, Charles Loi, and Vivek Kocharlakota, "IED Metrics for Iraq, June 2003–September 2010," Center for Strategic and International Studies (November 11, 2011), available at <[https://csis-prod.s3.amazonaws.com/s3fs-public/legacy\\_files/files/publication/101110\\_ied\\_metrics\\_combined.pdf](https://csis-prod.s3.amazonaws.com/s3fs-public/legacy_files/files/publication/101110_ied_metrics_combined.pdf)>.

<sup>5</sup> Eric von Hippel, "Lead Users: A Source of Novel Product Concepts," *Management Science* 32, no. 7 (1986), 791–805.

<sup>6</sup> *Ibid.*

<sup>7</sup> Everett M. Rogers, "Methods of Measuring Opinion Leadership," *Public Opinion Quarterly* (1962), 435–441; Geoffrey A. Moore, *Crossing the Chasm: Marketing and Selling High-Tech Products to Mainstream Customers* (New York: HarperCollins, 1991).

<sup>8</sup> Marvin B. Lieberman and David B. Montgomery, "First-Mover Advantages," *Strategic Management Journal* 9, special issue (Summer 1988), 41–58.

<sup>9</sup> Eric Ries, "Minimum Viable Product: A Guide," *Startup Lessons Learned* (August 2009), available at <[www.startuplessonslearned.com/2009/08/minimum-viable-product-guide.html](http://www.startuplessonslearned.com/2009/08/minimum-viable-product-guide.html)>.

<sup>10</sup> Eric von Hippel, "Lead Users," 791–805.

<sup>11</sup> Eric von Hippel, "'Sticky Information' and the Locus of Problem Solving: Implications for Innovation," *Management Science* 40, no. 4 (1994), 429–439.

<sup>12</sup> Nathan Rosenberg, *Inside the Black Box: Technology and Economics* (New York: Cambridge University Press, 1982).

<sup>13</sup> Michael Polanyi, *Personal Knowledge: Towards a Post-Critical Philosophy* (Chicago: University of Chicago Press, 1958).

<sup>14</sup> Barry D. Watts, *Sustaining the U.S. Defense Industrial Base as a Strategic Asset* (Washington, DC: Center for Strategic and Budgetary Assessments, September 18, 2013).

<sup>15</sup> *Ibid.*, 3.

<sup>16</sup> Arthur Herman, *Freedom's Forge: How American Business Produced Victory in World War II* (New York: Random House, 2012).

<sup>17</sup> Robert Martinage, *Toward a New Offset Strategy: Exploiting U.S. Long-Term Advantages to Restore U.S. Global Power Projection Capability* (Washington, DC: Center for Strategic and Budgetary Assessments, October 27, 2014), available at <<http://csbaonline.org/>>

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