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Assessing the State of Understanding of Defense Innovation

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The competition for innovation has become a priority for the world's major military powers. The United States and China are leading a global race in the development of new generations of technological capabilities, business approaches, and doctrinal and operational constructs, driven in large part by their growing strategic rivalry with each other. Many other countries, from Russia to Israel, have also unveiled defense innovation initiatives, but the scope and seriousness of these efforts vary widely, as detailed in other briefs in this compendium. How are we to assess contemporary defense innovation? The central focus in this brief is to make sense of different approaches to defense innovation by determining whether there are general patterns and characteristics that offer insights into questions such as why some states are able to pursue innovation at a faster rate or more advanced level than others, and the essential ingredients for successful innovation. This brief seeks to develop an understanding of the relationship between defense innovation and military innovation, and more specifically the linkages and interaction between the defense innovation system and the military establishment.

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WHAT IS DEFENSE AND MILITARY INNOVATION?

It is important to define precisely what is meant by defense innovation, and how it relates to its close cousins, most notably military innovation. Defense innovation is the transformation of ideas and knowledge into new or improved products, processes, and services for military and dual-use applications. It refers primarily to organizations and activities associated with the defense and dual-use civil-military science, technology, and industrial base. Included at this level are, for instance, changes in planning, programming, budgeting, research, development, acquisition, and other business processes.[1]

Military innovation refers primarily to warfighting innovation, modest or profound. It encompasses both product innovation and process innovation, and technological, operational, and organizational innovation, whether separately or in combination, intended to enhance the military's ability to prepare for, fight, and win wars.

Technology is the most visible dimension of military innovation, but military innovation is not to be equated with, or reduced to, technological innovation. Technology is not the be all and end all of military innovation. The organizational and doctrinal components of military innovation are no less significant than its technological component.[2]

Technology, in the form of weapons and weapons systems, serves as the source of the hardware dimension of military innovation and its concrete products.[3] Organizational and doctrinal changes, the software of innovation, provide what is characterized in the broader literature as process innovation. Realizing new technology's potential typically requires organizational adaptation and doctrinal development. Although military organizations are inclined to pursue technological developments that are in accord with their culture, it is not unusual for new technologies to encounter spirited organizational and bureaucratic resistance. Organizational restructuring or even the development of new organizations with new skill sets may be necessary. Similarly, new technologies, particularly those that qualify as breakthroughs, may well require revising the principles that shape or guide the employment of military force.

The three components of defense and military innovation—technology, organization, and doctrine—rarely change simultaneously; most often, one tends to lead while the others follow. Technology—information technology today, for instance—may leap ahead, requiring organizations and doctrine to play catch up, perhaps for decades. Warfighting, or doctrinal, visions, such as the transformation enterprise's network-centric warfare, can drive organizational change and technological development. The extent to which hardware and software innovation, and product and process innovation, are effectively integrated can determine whether change is likely to be continuous or discontinuous, sustaining or disruptive, incremental or transformational, evolutionary or revolutionary.

DRIVING DISRUPTIVE INNOVATION

Although innovations take many forms, historically the most consequential have been disruptive innovations. In the military realm, these have led to large-scale changes in the character and conduct of war, producing winners and losers and altering the geopolitical landscape.[4] In each case, new combat methods arose that augmented, displaced, or replaced previously dominant forms of warfare by shifting the balance between offense and defense, space and time, and fire and maneuver.[5] The militaries that first adopted these innovations gained a significant advantage, forcing competitors to match or counter them to have any chance of prevailing on the battlefield. Those who adapted prospered, while those who did not declined, often precipitously.

History shows that catalytic factors are central in bringing about disruptive innovation. The threat environment plays a key role. First, most disruptive innovations have come about because of the perception of an operational or strategic problem that defied a conventional solution. The urgency of action and the absence of incremental, routine alternatives is often necessary to break the strong preference of existing bureaucracies

1 Tai Ming Cheung, Thomas G. Mahnken, and Andrew L. Ross, "Frameworks for Analyzing Chinese Defense and Military Innovation," in *Forging China's Military Might: A New Framework for Assessing Innovation*, ed. Tai Ming Cheung (Baltimore, MD: Johns Hopkins, 2014).

2 A point emphasized in Andrew L. Ross, "The Potential Import of New, Emerging, and Over-the-Horizon Technologies," in *Emerging Critical Technologies and Security in the Asia-Pacific*, ed. Richard A. Bitzinger (New York: Palgrave Macmillan, 2016), 22–36.

3 On technology and the technological component of innovation, see Colin S. Gray, "Technology as a Dynamic of Defense Transformation," *Defense Studies* 6, no. 1 (2006): 26–51.

4 See Bernard Brodie, "Technological Change, Strategic Doctrine, and Political Outcomes," in *Historical Dimensions of National Security Problems*, ed. Klaus Knorr (Lawrence: University Press of Kansas, 1976); William H. McNeill, *The Pursuit of Power: Technology, Armed Force, and Society Since AD 1000* (Chicago: University of Chicago Press, 1982); Geoffrey Parker, *The Military Revolution*, 2nd ed. (Cambridge: Cambridge University Press, 1996); and Clifford J. Rogers, ed., *The Military Revolution Debate: Readings on the Military Transformation of Early Modern Europe* (Boulder, CO: Westview Press, 1995).

5 Eliot A. Cohen, "A Revolution in Warfare," *Foreign Affairs* 75 (March/April 1996): 43–44.

to apply their standard solutions to the problem. Indeed, innovation is often an unnatural act for organizations that are, by their very nature, meant to routinize rather than innovate.

Second, top-level leadership support is crucial to the success of disruptive innovation. Leaders often must ensure that the innovation effort receives the economic, technological, and human resources it needs to be successful and also defend it against those who would seek to kill or sideline it.

THE RELATIONSHIP BETWEEN THE DEFENSE INNOVATION SYSTEM AND THE MILITARY

The defense innovation system's primary—although not only—mission is the research, development, and acquisition of weapons and equipment for military end-users. Consequently, the interactions between these two systems will have a far-reaching effect on how well the needs of the war-fighter are served. In most countries, the defense innovation system is primarily civilian, rooted in the defense industrial apparatus and civilian research, development, and educational system. But there are also often important military components that work closely alongside the defense innovation system, especially the military procurement agencies and military research and development entities.

Ideally, the linkages between the defense innovation and military systems should be broad and deep. The key factors within the defense innovation system that would be most closely tied with military entities include:

Factors related to determining threat assessments and how they define war-fighter requirements at the strategic, operational, and tactical level. These factors, such as the threat environment and strategies and plans, would be closely coordinated with the formulation of military doctrines, strategies, and operational concepts.

Factors connected to the acquisition of weapons and equipment. The defense innovation system and the military establishment should be tightly coupled with each other in factors such as the acquisition process, technology push versus demand pull, and the production process.

In reality, there is often considerable friction and compartmentalization between these two systems, attributable to the principal-agent dilemma, in which the defense innovation system, or agent, acts in accordance with interests that do not necessarily correspond with those of the military establishment, or principal. Understanding the nature of this agency problem would be extremely useful in assessing the effectiveness of the defense innovation-military establishment relationship.

ASSESSING THE IMPACT OF INNOVATION

Despite the emphasis on revolutionary change in the literature on defense and military innovation, most innovation, as previously noted, is distinctly less than profound.[6] It consists of what is best characterized as near-continuous, incremental advances in existing capabilities. The significance of essentially routine incremental improvements in technology, doctrine, and organizational capabilities should not be minimized. On the hardware, or technology, front, it is what is thought of as modernization.

Sustaining (rather than disruptive) innovation is commonplace, even mundane.[7] Its incrementalism does not, however, diminish the significance of sustaining innovation, which is what military organizations, following standard operating procedures, regularly pursue. Technology evolves. Doctrine is improved. Organizations adapt. Extant capabilities are optimized. Military change on the order of military revolutions, revolutions in military affairs, and transformations, on the other hand, is an extraordinary, infrequent phenomena that entails profound, fundamental discontinuities. Such disruptive innovation—reminiscent of what Schumpeter termed "creative destruction"—underlies revolutions and transformations that are, by definition, extraordinary.[8] Technology races ahead. Doctrine and organizations alike are discarded and created anew. Innovation located between the two ends of this innovation spectrum, located in quadrants of the innovation matrix (Figure 1) other than that within which disruptive, revolutionary innovation appears, is too often neglected.

Discontinuous innovation poses the potential of technological or architectural "breakthroughs." Though less than revolutionary, breakthroughs, according to Mark and Barbara Stefik,

6 This material draws upon and develops work presented in Andrew L. Ross, "Framing Chinese Military Innovation," in *China's Emergence as a Defense Technological Power*, ed. Tai Ming Cheung (New York: Routledge, 2013), 187–213, and Cheung, Mahnken, and Ross, "Frameworks for Analyzing Chinese Defense and Military Innovation."

7 The distinction between sustaining and disruptive innovation employed here is drawn from Clayton M. Christensen, *The Innovator's Dilemma* (New York: Harper Business, 2000). Peter Dombrowski and Eugene Gholz further develop the concept of disruptive innovation in "Identifying Disruptive Innovation: Innovation Theory and the Defense Industry," *Innovations* 4, no. 2 (2009): 101–17.

8 Joseph A. Schumpeter, *Capitalism, Socialism, and Democracy*, 3rd ed. (New York: Harper & Row, 1950). The distinction between sustaining and disruptive innovation made by Christensen and employed here echoes that between incremental and radical innovation made by Rebecca Henderson in "Underinvestment and Incompetence as Responses to Radical Innovation: Evidence from the Photolithographic Alignment Equipment Industry," *RAND Journal of Economics* 24, no. 2 (1993): 248–70.

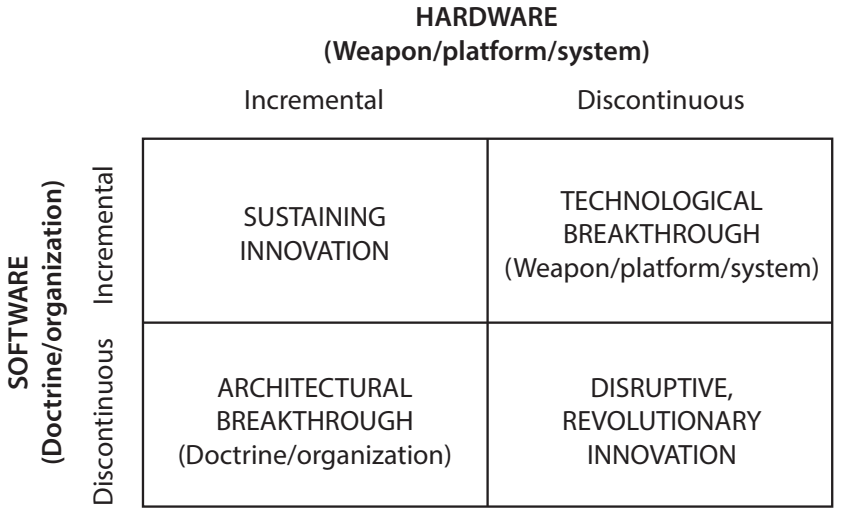

FIGURE 1. Innovation matrix

are rare and surprising. They "create something new or satisfy a previously undiscovered need" and enable us to do something that we did not know was possible.[9] The uses and consequences of breakthroughs can be unintended. They may transform or displace existing practices.

Discontinuous weapons, platforms, or systems—or hardware—change, even in the context of incremental doctrinal and/or organizational change, constitutes what is identified in Figure 1 as a "technological breakthrough." Discontinuous doctrinal and/or organizational—or software—innovations are depicted as architectural breakthroughs. Architectural innovation redefines the way in which the components of technologies, doctrines, or organizations are integrated. There are major changes in the relationships, or linkages, between hardware (technology) and software (doctrine and organization).[10] As Rebecca Henderson and Kim Clark put it, "The essence of an architectural innovation is the reconfiguration of an established system to link together existing components in a new way."[11] Dramatic departures in operational concepts or organizational structure—particularly the development of new doctrine or the establishment of new organizations—that result in extant technology being used in ways it has not been used before constitute architectural breakthroughs. Discontinuous technological and architectural innovations both occur more frequently than disruptive, revolutionary innovation but much less frequently than sustaining innovation.[12]

Disruptive, revolutionary innovation is the result of the confluence of discontinuous technological, doctrinal, and organizational changes; it occurs when discontinuous hardware and architectural changes come together in a coherent, integrated whole. Existing capabilities are not optimized but rendered obsolete and displaced. New dominant technologies, doctrines, and organizations are established and integrated as never before. New performance metrics—Christensen's "cheaper, simpler, smaller, and, frequently, more convenient to use," for instance—are introduced.[13]

Discontinuous innovation need not entail simultaneous technological, doctrinal, and organizational breakthroughs. Indeed, simultaneous hardware and architectural breakthroughs appear to be the exception rather than the rule. One tends to lead while the other lags and must catch

9 Mark Stefik and Barbara Stefik, *Breakthrough: Stories and Strategies of Radical Innovation* (Cambridge, MA: MIT Press, 2004), 3.

10 On the concept of architectural innovation, see Rebecca Henderson and Kim Clark, "Architectural Innovation: The Reconfiguration of Existing Product Technologies and the Failure of Established Firms," *Administrative Science Quarterly* 35, no. 1 (1990), 9–30.

11 Ibid., 12.

12 Examples of past discontinuous technological innovations include the introduction of battleships, aircraft, tanks, aircraft carriers, and, more recently, GPS. Today, UAVs and other unmanned, robotic systems are examples of discontinuous technological breakthroughs. The all-volunteer force, "jointness," and maneuver warfare are recent examples of architectural innovation. Blitzkrieg is a well-known historical example of an architectural breakthrough.

13 These are performance metrics that hold no small appeal to transformation's advocates; see Christensen, *The Innovator's Dilemma*, xviii. On the significance of performance metrics see Peter Dombrowski, Eugene Gholz, and Andrew L. Ross, *Military Transformation and the Defense Industry After Next: The Defense Industrial Implications of Network-Centric Warfare* (Newport, RI: Naval War College Press, 2012); and Peter Dombrowski and Eugene Gholz, *Buying Military Transformation: Technological Innovation and the Defense Industry* (New York: Columbia University Press, 2006).

up—if disruptive innovation rather than either a technological or architectural breakthrough alone is to be the result. Breakthrough doctrinal and organizational innovations have often lagged behind breakthrough technological innovations.

The prospect that continuous, sustaining innovation may over time eventuate in profound, disruptive innovation is not to be dismissed.[14] In the past, the phenomena characterized as military revolutions, revolutions in military affairs, and military-technological revolutions developed over considerable periods of time. Today, in the unmanned, robotic, artificial intelligence, and cyber realms, and underpinned by continuous improvements in information technologies, defense innovation systems may well provide militaries with the capabilities for missions once thought impossible, in new dimensions of the battlespace that may have the game-changing potential of rendering "previous methods of conducting war obsolete or subordinate," displacing "one form of war with another," or fundamentally changing the way war is waged.[15]

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14 As previously suggested by Andrew L. Ross, "The State of U.S. Defense Innovation," IGCC Defense Innovation Briefs, January 2014, https://escholarship.org/uc/item/6f86r0fm.

15 As envisioned in US Department of Defense, *Quadrennial Defense Review Report* (Washington, DC: Department of Defense, 2001), 29.