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Putting Innovation into Practice

Larry Lewis, David Knoll, Diane Vavrichek, Alexander Powell, Bradley Dickey, Ciro Lopez

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Abstract

Innovation is a key enabling concept in the 2018 National Defense Strategy. Not only does the US military need to continue to maintain effectiveness in military operations, but in the face of a new competitive environment, and the increasing importance of commercial technology, the US will need to practice innovation to maintain a military edge and meet national security goals. The critical role of innovation is repeated throughout the NDS. But what can the US do to pursue effective innovation? And what is innovation anyway? We examine innovation through consideration of specific military examples—both historical and contemporary—as well as examining academic literature and past CNA products addressing innovation. After developing a functional definition of innovation, we provide best practices and principles that DOD can apply in order to put innovation into practice.

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Dr, David Broyles, Director
Special Activities and Intelligence Program
Operational Warfighting Division

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14. ABSTRACT

Innovation is a key enabling concept in the 2018 National Defense Strategy. Not only does the US military need to continue to maintain effectiveness in military operations, but in the face of a new competitive environment, and the increasing importance of commercial technology, the US will need to practice innovation to maintain a military edge and meet national security goals. The critical role of innovation is repeated throughout the NDS. But what can the US to pursue effective innovation? And what is innovation anyway? We examine innovation through consideration of specific military examples—both historical and contemporary—as well as examining academic literature and past CNA products addressing innovation. After developing a functional definition of innovation, we provide best practices and principles that DOD can apply in order to put innovation into practice.

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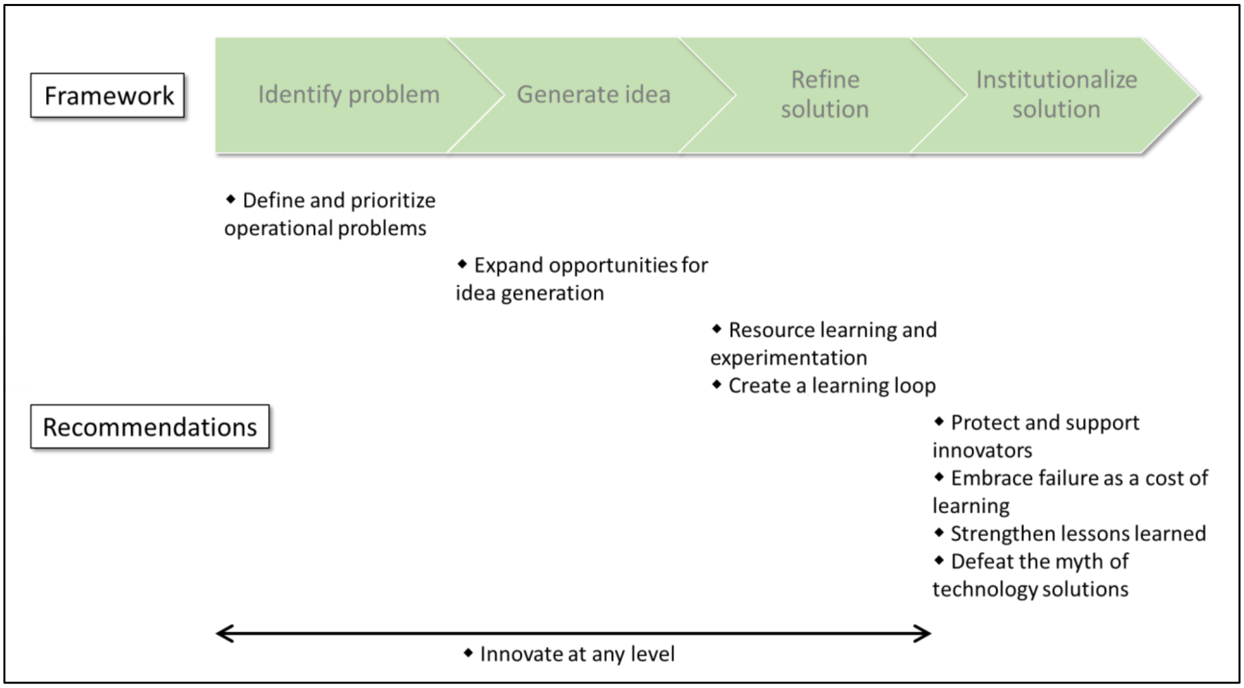
Executive Summary

Innovation is a key enabling concept in the 2018 National Defense Strategy (NDS). In this strategy, not only does the U.S. military need to continue to maintain effectiveness in military operations, but, in the face of a new competitive environment and the increasing importance of commercial technology, the U.S. will also need to practice innovation to maintain a military edge and meet national security goals. The critical role of innovation is repeated throughout the NDS. But what is innovation? And what can the U.S. do to pursue effective innovation?

We find there is not a consensus either inside or outside of DOD on the definition of military innovation. This means that individuals and organizations can do very different things and still claim they are pursuing innovation. To address this issue, we take a fundamental problem-solving approach, with the basic tenet: to solve a problem, we first need to define it. Hence, through consideration of DOD innovation efforts, academic literature, and past CNA publications, we develop a functional definition of innovation: "*a significant change in an organization and its operational practice potentially resulting in greater military effectiveness.*"

We find the primary focus of recent DOD initiatives on innovation is to accelerate the acquisition process. This is a narrower focus than the more comprehensive process we see in our definition of innovation. We conclude that DOD efforts today are necessary but not sufficient for advancing the successful innovation called for in the 2018 NDS. We also examine a number of case studies showing innovation in practice, which collectively illustrate both steps and challenges inherent in successful innovation. These examples show that military institutions do not naturally embrace many of the elements of innovation, and indeed can receive significant resistance that slows or stops needed progress. We provide a framework giving the steps needed for successful innovation and use that framework to provide recommendations for best practices and principles that DOD can apply in order to put innovation into practice, summarized in the figure below.



Recommendations for pursuing innovation include:

- **Develop a process to define and prioritize operational problems to help focus innovation efforts.** Leaders should ask: What are the most pressing operational problems that impact U.S. competitiveness? This assessment should consider a combination of strategy, analysis of future trends, assessments of competition's strategy and current and future capabilities, and analysis of previous operations. These operational problems then become a focus for U.S. military innovation efforts overall.

- **Expand opportunities for idea generation, dedicating resources to foster idea generation activities.** Innovation will be fostered by both encouraging and gathering ideas. Initiatives such as the Navy's NavalX represent ways to gather new ideas for innovation. Such initiatives can be replicated and decentralized to expand the net for catching ideas. Dedicating modest time and resources for activities—such as convening small discussion groups, inviting speakers, holding conferences, and maintaining an ongoing dialogue—can go a long way to better harness the considerable creativity and expertise of individuals in the U.S. military.

- **Resource learning and innovation by conducting experimentation, running wargames, and conducting robust assessments to refine ideas and develop solutions.** After generating an idea, the next step—refining a solution—is more difficult and more resource-intensive. This step involves efforts to validate the idea, conduct experimentation, run wargames, and couple these activities with robust assessments. Such efforts help to quantify performance and identify strengths, weaknesses, and opportunities for improvement. History shows these assessment and experimentation activities can be difficult to sustain as they receive scrutiny as military leaders ask whether they are worth it. Perhaps these budgeting decisions would benefit from considering the NDS recipe for success in competition: "a more lethal, resilient, and rapidly innovating Joint Force." How much is spent on lethality? On resiliency? If the 2018 strategy is correct and innovation is an essential component of the U.S. prevailing in a new era of competition, then budgets should support this priority as well.

- **Create a learning loop by coupling experimentation, assessment, and wargame activities, synchronized by a learning campaign plan to provide feedback and improved learning.** The historical examples of innovation show that experimentation, wargames, and assessments are critical to successful innovation. They also show that they are particularly effective when conducted in an iterative way, creating a learning loop. Historically this has largely been an ad hoc development, but this need not be the case in future innovation efforts. Coupling experimentation with studies/assessments and wargaming should be a standard approach to the most promising and potentially high-impact innovation ideas. This should be facilitated by creating a campaign plan for learning that sets out activities in experimentation, assessments, and wargames and specifies how they will feed into each other, reinforcing each other for more effective, iterative improvements and refinements. Such a deliberate approach will help accelerate the innovation process as well as make it more effective.
- **Protect and support innovators when their ideas and initiatives can be seen as threatening to the status quo.** Military organizations are incentivized to sustain the status quo as a necessity of running a large organization where failure is not seen as an option. Because new ideas can be threatening in that environment, they have often been attacked by organizational antibodies defending what they see as a threat. History shows that senior leaders actively protecting and supporting the practical innovators—those developing concept of operations or doctrine, those spearheading experimentation efforts, those trying to lead those new ideas onto the battlefield—serves to accelerate the innovation process.
- **Embrace failure as a cost of learning, providing a safe environment for innovation efforts.** NASA's credo—failure is not an option—could also apply to the U.S. military and its mission for preserving national security. There are certain contexts where failure would have an unacceptable cost to the nation. But care needs to be taken that this credo is applied only in the context of those critical missions. In the bigger picture, the U.S. military needs to fail in order to not fail. Failure is a valuable tool in learning when it occurs in contexts that are safe and not mission-critical, when the possibility of failure is accompanied by a process for assessment and learning. When

there is broader applicability, lessons from those failures should be shared more broadly so that the rest of the institution can benefit from that experience. Such a process can be instituted to include cases of innovation, documenting not only what worked but also what did not and an assessment of why. Likewise, innovators experiencing failure should be seen as a good sign: a sign that learning is happening and that the military is providing a safe environment for innovation.

- **Improve lessons-learned processes to avoiding the mistakes of the past: better resource efforts to identify lessons and then draw upon those lessons in decision-making.** Studying past operations and identifying lessons regarding what worked, what did not, and why, can help the military to be a better learning organization. However, the U.S. military has struggled with this, often shortchanging the resources and structures that provide insights needed for institutional learning. Thus, it has been observed that there is only a weak tie between identified lessons and institutional change. One potential reason for this could be a belief that the past is less important than the present and future, thus there is no value—or even perhaps a risk—of trying to understand past lessons. Historian Williamson Murray has refuted this view, saying "Historians have often suggested that military organizations study the last war and that is why they do badly in the next. In fact, few military organizations study the past with any degree of rigor, although the success of those that do so has demonstrated its vital importance."[1] To better enable innovation, the U.S. military should improve its ability to learn key lessons and avoiding the mistakes of the past, better resourcing its efforts to identify lessons and then drawing upon those lessons in decision-making. This does not simply happen; rather, it requires leaders to insist on it.

- **Defeat the myth of technology solutions to war: emphasize and resource innovation along with technology initiatives in order to present complex problems for competitors to address.** Then Chief of Staff of the Army Mark Milley described the belief that "wars can be won with advanced technologies" as a myth—a myth that can influence senior leaders, policy-makers, and political leaders to emphasize technology in budgets, force structure, and operational plans and concepts.[2] Today, the promise of artificial intelligence, autonomous weapons, hypersonic weapons, and networks of fused surveillance and intelligence can seem to be the answer to competition. In truth, they are only part of a more comprehensive solution: relying on lethality but also resiliency and innovation to present complex challenges

[1] Williamson Murray, "Military Culture Does Matter," *FPRI*, Jan. 21, 1999, https://www.fpri.org/article/1999/01/military-culture-does-matter/.

[2] Minutes, National Press Club Headliners Luncheon with U.S. Army Chief of Staff General Mark Milley, Jul. 27, 2017, https://www.press.org/sites/default/files/20170727_milley.pdf.

for adversaries that they cannot prevail against. In the same way that the U.S. military pursues lethality through technological capabilities, innovation should also be front and center in its efforts to win in this competition. Consequently, the elements needed for innovation described in this report need to be prioritized and resourced by leaders as much as technology solutions.

- **Seek innovation at any level.** Individual units or commands can explore new ideas and solutions to a variety of operational problems, creating bottom-up as well as top-down innovation. History is replete with examples where individual units at various echelons had an idea, experimented with the idea, and it resulted in fundamental changes in warfighting. For example, in 1980, 2nd Marine Division set out to explore the concept of maneuver warfare, experimenting and developing concept of operations and draft doctrine, and those ideas were adopted by the service as a whole. Of course, not every soldier, sailor, marine, or airman has the capacity to consider innovative ideas, as the U.S. military has many competing requirements. But history shows that a command or unit at any level can innovate and potentially change the force in unexpected ways.

While some of these recommendations can only be achieved by senior leaders, others can be done at any level, and indeed they should be. But ultimately, successful innovation will require these actions, both to create an environment where innovation flourishes and to push past institutional resistance to enable more rapid progress. With the military edge of the U.S. newly contested by determined competitors, in a new era where technological development is both revolutionary and ubiquitous, such actions will be vital for the U.S. to maintain national security.

Contents

Innovation for a New Era of Competition

From World War II to the end of the Cold War in 1991, the U.S. focused on deterring and defeating threats from nation states. But in 1991, with a Soviet threat seemingly evaporating as the Soviet Union broke into smaller pieces, the U.S. shifted to a mission of Military Operations Other Than War (MOOTW), featuring humanitarian and peacekeeping interventions. The National Security Strategy of 2000 discussed "record prosperity" with "no overriding threats abroad" and the main aims were seen as strengthening alliances and global norms to promote U.S. values and enhance international stability.[3] Notably, in 2001 the newly inaugurated president discussed his intent to shift the military's focus back to responding to the threats posed to the U.S. from nation states, but this shift was interrupted by the events of a single day: when terrorists attacked the U.S. homeland on September 11 with hijacked commercial airplanes.

After what is now known as "9-11," the resulting conflicts in Afghanistan and then in Iraq featured rapid-paced military operations, but in both cases they transitioned to extended and unforeseen stability and counterinsurgency operations against non-state armed groups. The U.S. also pursued a largely kinetic approach towards Al Qaeda and affiliated groups in other locations around the world. The U.S. adapted its approaches and developed new capabilities to better target these non-state armed groups in the two decades since 9-11. However, in that time, while the U.S. pursued largely irregular warfare, peer competitors such as China and Russia worked to erase technological advantages held by the U.S. military.[4] Their efforts both emulated U.S. approaches, such as network-based warfare and precision-guided munitions, and sought to offset U.S. capabilities, through approaches such as jamming of U.S. communications and GPS satellites used for navigation and targeting and the development of advanced hypersonic missiles that stressed U.S. defensive capabilities.[5] As a result, the U.S. lost

[3] "A National Security Strategy for a Global Age," The White House, Dec. 2000.

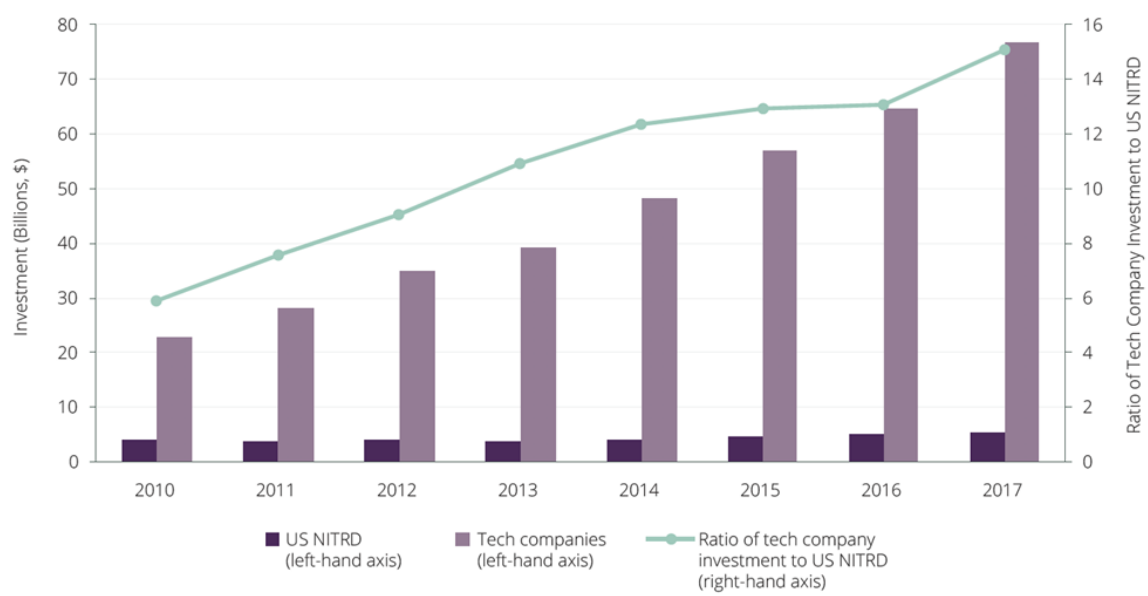
[4] Secretary of Defense Chuck Hagel, keynote speech delivered at Reagan National Defense Forum, Ronald Reagan Presidential Library, Nov. 15, 2014, https://www.defense.gov/News/Speeches/Speech-View/Article/606635/.

[5] Cheryl Pellerin, "Deputy Secretary: Third Offset Strategy Bolsters America's Military Deterrence," *DOD News*, Oct. 31, 2016, https://www.defense.gov/News/Article/Article/991434/deputy-secretary-third-offset-strategy-bolsters-americas-military-deterrence.

ground in terms of its dominant technological advantage that has historically given the U.S. a military edge over its competitors.

At the same time, the U.S. military can no longer rely on its own Research and Development (R&D) resources to maintain such a technological advantage over competitors. The tech industry had increased its R&D investments dramatically in recent years, now greatly exceeding that of the entire U.S. government. For example, in 2010, R&D investments by the top five U.S. tech companies (Amazon, Google/Alphabet, Intel, Microsoft, and Apple) represented six times the overall technology R&D investment of the U.S. government, with that ratio growing to 15 times just 8 years later. Overall, the U.S. faces a rapidly growing gap in research investment in cutting edge technology.

Figure 1. Growing R&D investment gap between U.S. government and tech sector



Source: Graph derived from data accessed at https://www.statista.com/statistics/273006/apple-expenses-for-research-and-development/; https://notesmatic.com/amazon-research-and-development-expenses/; https://notesmatic.com/alphabet-research-and-development-expenses/; https://www.statista.com/statistics/263562/intel-expenditure-on-research-and-development-since-2004/; https://notesmatic.com/microsoft-research-and-development-expenses/; https://www.nitrd.gov/about/#History.

These two developments—a new competition with peer competitors and the new widespread availability of technological advancements because of the tech sector's new dominance in

R&D—have significant implications for U.S. national security. They are reflected in the 2018 National Defense Strategy (NDS). As then Secretary of Defense Mattis described when the new strategy was announced:

> We face growing threats from revisionist powers as different as China and Russia are from each other, nations that do seek to create a world consistent with their authoritarian models, pursuing veto authority over other nations' economic, diplomatic and security decisions...
>
> In this time of change, our military is still strong. Yet our competitive edge has eroded in every domain of warfare, air, land, sea, space and cyberspace, and it is continuing to erode.[6]

The 2018 NDS also offers a remedy for this situation:

> A more lethal, resilient, and rapidly innovating Joint Force, combined with a robust constellation of allies and partners, will sustain American influence and ensure favorable balances of power that safeguard the free and open international order.[7]

A key enabling concept in the NDS is innovation. Not only does the U.S. military need to continue to maintain effectiveness in military operations, but in the face of a new competitive environment and the increasing importance of commercial technology, the U.S. will need to practice innovation to maintain a military edge and meet national security goals. The critical role of innovation is repeated throughout the NDS. For example: "A more lethal force, strong alliances and partnerships, American technological innovation, and a culture of performance will generate decisive and sustained U.S. military advantages."[8]

Innovation can be Decisive—but What is It?

The critical role of innovation in national security has been understood long before the 2018 NDS. For example, from academic literature examining past military operations, "it is commonly understood that countries that fail to develop and successfully adopt new military

[6] Secretary of Defense James N. Mattis, Remarks by Secretary Mattis on the National Defense Strategy, Jan. 19, 2018, https://www.defense.gov/Newsroom/Transcripts/Transcript/Article/1420042/remarks-by-secretary-mattis-on-the-national-defense-strategy/.

[7] DOD, Summary of the 2018 National Defense Strategy, Jan. 19, 2018, https://dod.defense.gov/Portals/1/Documents/pubs/2018-National-Defense-Strategy-Summary.pdf.

[8] Ibid.

innovations may experience an erosion of their military power."[9] A commonly cited example of innovation is the invention and adoption of the tank, and its role in World Wars I and II. This example serves to illustrate both the importance and the complexity of innovation.

Both the UK and France experimented with the idea of armored vehicles using the combustion engine for mobility on the battlefield, inspired by early tractor designs.[10] But these experiments did not lead to any developments until the start of World War I and the phenomenon of trench warfare. Then, the possibility of an armored vehicle that could breech the stalemate of held areas became a desirable capability.[11] The UK was the first to develop and field the "tank," named thus because the UK portrayed them as water tanks as a deception measure.[12] Limited in their speed and ability to maneuver, tanks were featured operationally for the first time in October 1917 in the Battle of Cambrai, where a surprise offensive penetrated a German defensive line. This operation was widely celebrated by the British, but the success was short-lived: German forces retook the captured territory a few days later while pushing the British defensive line back, a net loss for the operation.[13] In contrast, the British successfully used the tank to penetrate the German defensive line in the Battle of Amiens on August 8, 1918, showing the vulnerability of German forces weakened by years of attrition warfare and demonstrating the value of tanks in warfare.[14]

After the war, while the value of tanks was clear, the British did not seriously consider operational lessons for the tank for over a decade.[15] This is consistent with Williamson Murray's observation about military learning: "It is a myth that military organizations tend to do badly in each new war because they have studied too closely the last one; nothing could be farther from the truth. The fact is that military organizations, for the most part, study what makes them feel comfortable about themselves, not the uncongenial lessons of past conflicts.

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[9] Michael Horowitz and Shira Pindyck, What is a Military Innovation? A Proposed Framework, SSRN, Dec. 2019, https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3504246.

[10] Interestingly, H.G. Wells described the concept of the tank in a short story in 1903, years before militaries began exploring the concept, illustrating how science fiction can help inform the art of the possible in warfare. H.G. Wells, "The Land Ironclads," *The Strand Magazine* 23(156): 751–769.

[11] Ernest Swinton, Eyewitness, Ayer Publishing, 1933.

[12] A.G. Stern, Tanks 1914–1918: The Log Book of a Pioneer, Hodder & Stoughton, 1919.

[13] Terry C. Pierce, Warfighting and Disruptive Technologies: Disguising Innovation, Frank Cass Publishing, 2004.

[14] Description of the Battle of Amiens, accessed Aug. 24, 2020, https://www.warmuseum.ca/firstworldwar/history/battles-and-fighting/land-battles/amiens/

[15] Ibid.

The result is that more often than not, militaries have to relearn in combat—and usually at a heavy cost—lessons that were readily apparent at the end of the last conflict."[16]

In contrast, the Germans used the aftermath of WWI to examine lessons and operational concepts that took advantage of the capabilities that tanks offered. This examination included both lessons from its own, more limited, tank operations in WWI and observations from British experimentation with tanks in the 1920s (experiments that helped inform German concepts of tank maneuver but were ignored by the British military institution).[17] As a result, the Germans developed a doctrine and operational concept for integrating tanks into larger units to achieve effective maneuver warfare in the 1920s, despite the fact that—because of restrictions on the German military imposed on them by the international community after WWI—they had no actual tanks. Instead, they did experiments and exercises, exploring the combination of tanks with other maneuver elements, and then combining radios to allow for strong coordination, agile maneuvers, and combined arms fires, ending in the Blitzkrieg doctrine used to great effect by Germany in World War II.[18]

This example shows several things. First, innovation can have a significant effect on national security. There is wide agreement that the military innovation of the Blitzkrieg approach led to a rebalance of military power that Germany benefitted from in World War II. But second, the definition of innovation is still variable. Is it invention of military technology? If that is so, then the British were the true innovators as they developed the tank. Is it invention of new operating concepts? If so, then the British again led the charge with some of their experiments in the 1920s—experiments that the military institution did not heed, but the Germans learned from. Or is innovation the fielding of disruptive capabilities on the battlefield? The way we define innovation matters, both for setting expectations for what it can achieve and for the steps that must be taken to promote it.

Aims of this Report

In this report we examine critical aspects to successful innovation. If innovation is central to the national security of the U.S., how can the U.S. successfully innovate? To answer that question, we first need to answer the fundamental question: What is innovation? In the next

[16] Williamson Murray, "Thinking About Innovation," *Naval War College Review* 54(2) (Spring 2001).

[17] For example, in 1934, General Sir Alexander Godley, the British commander of their cavalry stated: "If I were asked, 'Will you go to war with a mobile force composed [of] armored cars, tanks, and such-like?' I think I should refuse to go! I should say that I would not go without a force of cavalry, I should want, and should insist on having, an ample portion of mounted troops." Williamson Murray, Armored Warfare, in Williamson Murray and Allan Millett (eds.), Military Innovation in the Interwar Period, Cambridge University Press, 1996.

[18] Terry Pierce, Warfighting and Disruptive Technologies, 2004.

section, we look at ways to define the task of innovation, finding that there is not a consensus either inside or outside of DOD on what innovation entails. Since it is necessary to first define a problem before it can be effectively solved, we develop a working definition to that end.

Next, understanding the components of innovation can help us understand what steps are necessary to make innovation successful. In the following section, Innovation Close Up, we flesh out our definition using historical examples of military innovation and some best practices for innovation from industry. We also examine a contemporary example of innovation in the context of a Navy ship, illustrating what is possible in the context of a single vessel or unit. The last section, Putting Innovation into Practice, gives some considerations for how DOD can put effective innovation in practice—steps that can help DOD better meet its NDS goals in a new era of competition.

Defining Innovation

> *If I had only one hour to solve a problem, I would spend up to two-thirds of that hour in attempting to define what the problem is.*[19]

Innovation is not simply a new idea in the 2018 NDS; there is broad consensus that innovation is a key ingredient to successful warfighting. For example: "A study of modern warfare suggests that whoever is first to combine new technologies with disruptive doctrine [a combination the author describes as 'disruptive innovation'] can gain a decisive advantage. Conversely, a military that is slow to adapt new ways of warfighting to technological advances opens itself to catastrophic defeat."[20] Considering how critical innovation is to success, militaries should seek to outperform their competitors in innovation—and the 2018 NDS indeed holds this as a goal. But in order to pursue successful innovation, it is helpful to first consider what innovation is. A dictionary definition begins to speak to the nature of innovation—"a new idea, method, or device; the introduction of something new"[21]—but what does this mean in a military context? We consider three sources to help understand the nature of innovation: DOD organizations, previous CNA publications, and academic literature. We examine attributes of each and then use them collectively to develop a functional definition of innovation. The goal is to have a definition we can use to then answer the question: How can DOD more effectively promote innovation?

DOD and Innovation

For understanding a DOD perspective on innovation, we first turn to the DOD Dictionary of Military Terms. The DOD Dictionary is an authoritative source of definitions for many terms as they are used by military forces, but innovation is not included. Despite the word being used 12 times in the NDS, innovation is also not defined there. Overall, we were unable to find an official DOD definition for innovation.

But definitions can also be surmised by how a word is used. We can get a picture of DOD's view of what innovation is by considering the nature of organizations that are intended to promote

[19] Attributed to the head of the Industrial Engineering Department of Yale University. Also, sometimes, without evidence, credited to Albert Einstein. https://quoteinvestigator.com/2014/05/22/solve/.

[20] Terry Pierce, Warfighting and Disruptive Technologies, 2004.

[21] Definition of innovation, www.meriam-webster.com, accessed Aug. 23, 2020.

it. We examine innovation organizations at the DOD level as well as within the Department of the Navy.

A wide array of DOD-wide innovation offices exist that are responsible for the entire department and its constituent agencies. These offices serve different purposes, exist at different levels within DOD, and report to different "higher headquarters." Some are merely advisory in nature. Others variously develop specific tailored capabilities, build human capital, and exist to better connect the public and private sector. They all aim to further innovation within DOD.

Defense Advanced Research Projects Agency (DARPA)

Founded in 1958 to help mitigate strategic surprise, DARPA was in many ways DOD's first innovation office.[22] In general, DARPA focuses its efforts on longer-term challenges. The current director, Dr. Steven Walker (2017–present), recently noted that DARPA thinks in terms of decades.[23] Although DARPA has no specific technological focus, Walker currently has four priorities for the agency—help defend the homeland from existential threats (such as those posed by cyberweapons, dirty bombs, and weapons of mass destruction); help the U.S. compete with peer adversaries (e.g., through development of hypersonics); help the U.S. conduct stabilization operations more effectively; and win the technology races of the 21st century (including artificial intelligence).[24]

Strategic Capabilities Office (SCO)

The SCO is a relatively new office, created in 2012 by then Deputy Secretary of Defense Ash Carter. According to DOD's FY 2017 budget request, it was established to "identify, analyze, demonstrate, and transition game-changing applications of existing and near-term technology to shape and counter emerging threats."[25] If this remains the SCO's mission, the near-term focus would differentiate it from organizations like DARPA, which typically focus on long-term projects.

[22] DARPA home page: https://www.darpa.mil/.

[23] Dr. Steven Walker, remarks at "Implementing Innovation: The 21st Century National Security Innovation Partnership Conference" event, CSIS, Washington, DC, Sep. 23, 2019.

[24] Ibid.

[25] Office of the Under Secretary of Defense (Comptroller), Defense Budget Overview: United States Department of Defense Fiscal Year 2017 Budget Request, Feb. 2017.

Little is publicly known about the SCO or its activities. However, Michael Griffin, current Under Secretary of Defense (USD), R&E, recently moved the SCO to sit under DARPA, a move he claimed would increase efficiencies without creating additional bureaucracies.[26]

Defense Innovation Unit (DIU)

Secretary of Defense Ash Carter stood up DIU in 2015 as the Defense Innovation Unit Experimental (DIUx).[27] In August 2018, Acting Secretary of Defense Patrick Shanahan announced the office would henceforth remove the "experimental" from its name.[28] DIU, which initially had a single location based in Silicon Valley, was initially marred by failure. Notably, Secretary Carter responded by quickly intervening to learn the lessons of its early challenges and adapting the organization, overhauling its leadership, structure, and mission.[29] Since then, it has expanded and now has satellite offices in Boston, Austin, and the Pentagon. DIU serves as a pseudo-venture capital firm, investing in companies (often times smaller companies that might not otherwise work with DOD) to solve national security problems. Using an instrument called other transactional authority (OTA), DIU can skirt the traditional lengthy defense acquisition process to engage companies faster.[30]

National Security Innovation Network (NSIN)

Formerly known as MD5, the NSIN works to build human capital as opposed to investing in specific technologies. The NSIN "aims to educate and build a network of innovators and entrepreneurs equipped with the incentives, expertise, know-how, and resources required to successfully develop, commercialize and apply DoD technology."[31] NSIN's website claims its programs "develop a new alliance between defense, academia, and venture communities

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[26] Aaron Mehta, "Griffin makes case for why SCO should live under DARPA—and why its director had to go," *Defense News*, Aug. 8, 2019.

[27] DIU home page: https://www.diu.mil/.

[28] Aaron Mehta, "Experiment over: Pentagon's tech hub gets a vote of confidence," *Defense News*, Aug. 8, 2018, https://www.defensenews.com/pentagon/2018/08/09/experiment-over-pentagons-tech-hub-gets-a-vote-of-confidence/.

[29] Ben Fitzgerald and Loren Dejonge Schulman, "The DIUx Is Dead. Long Live The DIUx," *Defense One*, May 12, 2016.

[30] Budden and Murray, "Defense Innovation Report," p. 20.

[31] Mike Gruss, "The Pentagon wants to create a broader network of innovators," *C4ISRNet*, May 13, 2019, https://www.c4isrnet.com/pentagon/2019/05/13/the-pentagon-wants-to-create-a-broader-network-of-innovators/.

whose collaboration is imperative in the service of our national security."[32] It does so partly by supporting such initiatives as "Hacking for Defense (H4D)."[33] In this sense, the NSIN is best viewed as an enabler—building expertise and bringing together the right people from the public sector, private sector, and academia to solve national security challenges.

Defense Innovation Board (DIB)

Secretary of Defense Carter created the DIB in 2015 to act as a "change agent" for DOD with regard to fostering innovation. The DIB is not an independent agency but rather an advisory board.[34] Chaired by former Google CEO Eric Schmidt (2015–present), it is designed to bring in outside experts (particularly from Silicon Valley) to help solve national security challenges. The DIB writes reports, holds quarterly meetings, and produces actionable recommendations; although, not technically part of DOD, it does not itself implement those recommendations.[35]

According to its charter, the DIB "shall provide the Secretary of Defense and the Deputy Secretary of Defense, through the USD(R&E), independent advice and recommendations on innovative means to address future challenges in terms of integrated change to organizational structure and process, business and functional concepts, and technology applications."[36]

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[32] National Security Innovation Network website, Mission page, undated, https://www.nsin.us/mission.

[33] From the NSIN website: "Hacking for Defense (H4D) is a semester-long course at top-tier research universities that offers the U.S. Department of Defense (DOD) leaders with the opportunity to collaborate with talented student teams to develop innovative solutions to their most pressing national security problems. The course teaches students to apply the Lean Startup methodology to solve real national security problems. Through student teams, the DOD is provided an avenue to connect with problem-solvers from academia, the private sector, and other nontraditional DOD actors." National Security Innovation Network website, Hacking for Defense (H4D) page, accessed Sep. 14, https://www.nsin.us/hacking-for-defense/.

[34] Budden and Murray, "Defense Innovation Report," p. 15.

[35] Another science advisory group, called JASON, was recently cut loose from USD(R&E). Formed during the Cold War to advise the Department of Defense, the group examined a wide array of topics. However, in April 2019, DOD confirmed that "after the expiration of the Program Management Task Order, there will be no active OUSD(R&E) sponsored contractual vehicles with MITRE for the JASON program." See: Aaron Mehta, "Pentagon confirms it is ending the Jason advisory contract, but group's work may continue," *Defense News*, Apr. 11, 2019.

[36] Defense Innovation Board Charter, amended Jun. 28, 2018, https://media.defense.gov/2019/Apr/02/2002108792/-1/-1/0/DIB.CHARTER_2018-2020_AMENDMENT_2018.06.28.PDF. For more information, see their home page: https://innovation.defense.gov/.

Defense Digital Service (DDS)

The same year Secretary of Defense Carter created the DIB, he also established the Defense Digital Service, described as a "SWAT team of nerds that provides the best in modern technical knowledge to bolster national defense." Stated to be made up of world-class software developers and related experts, the DDS focuses on high-impact projects where technology can be applied quickly. Past projects include strengthening DOD cybersecurity, a collaboration with the Defense Health Agency helping them to digitize their inventory of tissue samples, and working to strengthen counter-drone defense systems.[37]

Naval Expeditions (NavalX) Agility Office

In February 2019, Assistant Secretary of the Navy for Research, Development, and Acquisition (ASN RD&A) James "Hondo" Geurts[38] announced the creation of the NavalX Agility Office. NavalX is an attempt to create more open pathways by which sailors and Marines with innovative ideas can connect with those (in the DOD, in academia, or in the private sector) able to help implement them.[39] It is designed to be a ground-up approach to innovation. NavalX is envisioned to help enable cross-talk between those already working on innovative technologies who may not otherwise interact in order to avoid duplication of effort.[40] Rather than building discrete capabilities itself, the office's mission is one of empowering sailors and Marines at lower levels.[41] It has four lines of effort: generating playbooks for the Navy and DOD on how to use specific tools developed, creating tech bridges aimed at connecting the Navy with the private sector and academia, hosting launch platforms such as panel discussions and workshops, and recognizing successes through awards and stories.[42]

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[37] Defense Digital Service home page, https://dds.mil/.

[38] We note that James Geurts also established SOFWERX, discussed below.

[39] Megan Eckstein, "Navy Rolls Out NavalX Agility Office to Connect Innovators With Support, Tools," *USNI News*, Feb. 14, 2019, https://news.usni.org/2019/02/14/navy-rolls-navalx-agility-office-connect-innovators-support-tools.

[40] Mike Gruss, "The Navy's new plan for agility," *C4ISRNet*, Feb. 14, 2019, https://www.c4isrnet.com/show-reporter/afcea-west/2019/02/15/the-navys-new-plan-for-agility/.

[41] Eckstein, "Navy Rolls Out NavalX Agility Office to Connect Innovators With Support, Tools;" "NavalX – 04102019," YouTube video, uploaded Apr. 20, 2019.

[42] NavalX, "Our Lines of Effort," website, undated, https://www.secnav.navy.mil/agility/Pages/default.aspx.

Naval Innovation Process Adoption (NIPA)

The NIPA is an initiative created by the Office of Naval Research (ONR) aiming to develop a common approach to solving problems.[43] Announced in March 2018, NIPA is based on "lean" start-up acquisition practices, "following in the footsteps of DoD's Defense Innovation Unit Experimental (DIUx) and other military organizations in turning to tech companies' business practices to increase the pace of research and award contracts faster."[44] It is envisioned to accelerate acquisition and the provision of new technology for the Navy and the Marine Corps.[45]

Special Operations Forces Works (SOFWERX)

SOFWERX is a technology accelerator located in Tampa, Florida (but not within the confines of SOCOM headquarters). It was stood up in 2015 by SOCOM acquisition executive James Geurts, and was created via a partnership intermediary agreement (PIA) between the Doolittle Institute (now DefenseWerx) and SOCOM.[46] A PIA allows the government to leverage an outside entity (in this case DefenseWerx) to serve as an intermediary in performing services such as creating and running the SOFWERX venue.[47]

SOFWERX "acts as a marketplace for SOCOM to swiftly bring its special challenges to a civilian audience, and to help industry, academia, and government labs to offer new ideas to some of the hardest problems facing special operations teams."[48] Rather than creating specific products or investing in companies, SOFWERX provides a forum for SOCOM to interface with (often small) businesses to solve specific challenges facing operators. For example, SOFWERX hosts

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43 David Smalley, "Office of Naval Research Wants to Innovate at Startup Speed," Office of Naval Research Corporate Strategic Communications, Mar. 29, 2018, https://www.onr.navy.mil/en/Media-Center/Press-Releases/2018/ONR-NIPA-Startup-Innovation.

44 Scott Maucione, "Office of Naval Research is DOD's newest organization to set up innovation cell," *Federal News Network*, Apr. 3, 2018, https://federalnewsnetwork.com/defense-main/2018/04/office-of-naval-research-is-dods-newest-organization-to-set-up-innovation-cell/.

45 Ibid.

46 Michael Bottoms, "SOFWERX: A smart factory of innovation helping the warfighter," USSOCOM Office of Communication, Feb. 2, 2018, https://www.socom.mil/Pages/SOFWERX--A-smart-factory-of-innovation-helping-the-warfighter.aspxhttps://www.socom.mil/Pages/SOFWERX--A-smart-factory-of-innovation-helping-the-warfighter.aspx.

47 Kelly Stratton-Feix and Tambrein Bates, "SOFWERX," brief to SOFIC, May 2017.

48 Budden and Murray, "Defense Innovation Report," p. 24.

events such as hackathons, tech talks, and rapid prototyping events. SOCOM's acquisition executive and SOFWERX can make acquisition decisions and deploy funding for projects.[49]

Summarizing DOD Innovation Organizations

Considering these innovation organizations, we found that they fall into three categories: builders, connectors, and enablers.

- **Builders.** The most common DOD innovation organization is what we describe as "builder" organizations. This includes DARPA, DIU, DDS, NIPA, SOFWERX, and SCO. They create (or directly fund) technological solutions. For example, DIU provides direct funding to (often small) businesses in the form of pilot contracts to get technology to solve specific challenges.
- **Connectors.** Organizations such as NavalX and SOFWERX provide a forum to bring together warfighters with those capable of solving their problems. For example, NavalX does not build widgets. It aims to open pathways of communication to share innovation best practices among and between sailors, marines, academia, and the private sector. We note that SOFWERX acts both as a connector and as a builder.
- **Enablers.** DIB and NSIN build or source the human capital requirements necessary to advance innovation efforts. For example, DIB brings in outside experts from industry to provide recommendations on DOD innovation efforts. However, it does not operationalize these recommendations.

We note that the majority of DOD innovation organizations are builders, focused on the acquisition of technological solutions. This suggests that, within the DOD community, innovation is often considered synonymous with acquiring new technology.

CNA Publications

We also considered past CNA publications that address innovation. Specifically, we examined 22 CNA products written over the last 25 years that had "innovation" in the title, the abstract, or as one of the key words for the document. The documents fell into three categories:

- **Defined.** The authors defined what they considered to be innovation.

[49] For more information, see the SOFWERX website Events page, https://www.sofwerx.org/events/.

- **Described.** The authors did not define innovation, but they described in some way what they meant by the term.
- **Unclear.** The authors used the term innovation but did not define or describe it.

Overall, four CNA documents defined innovation while eight described innovation. The authors of the remaining 10 documents neither defined nor described what they meant by the term.

The four explicit definitions of innovation given in CNA documents are:

- Innovation is "doing something differently than the way it is currently done."[50]
- Innovation "involves choosing the right invention (out of many potential candidates) and making it into a commercially viable product."[51]
- "Innovation creates new goods and services or identifies more inexpensive and efficient ways of producing current goods and services."[52]
- "Tactically innovative [is an organization] using its own initiative and resources to incorporate new technologies and improve tactics used by other groups."[53]

The eight descriptions of innovation are:

- "Experimental operational development"[54]
- "Innovation often combines doctrine with hardware"[55]
- Possibly pertaining to both military technology and to new tactics and means of operating[56]
- A way to "achieve high velocity learning at every level"[57]

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[50] Framework for MCWL Experiments, CNA, Mar. 20, 2003.

[51] Dan Davis, Can Economic Models of Innovation inform Navy Acquisition Choices?, CNA, May 12, 2009.

[52] Aline Quester, Innovation and Production, CNA, Jan. 23, 2009.

[53] Julia McQuaid, Emily Warner, William Rosenau, Afshon Ostovar, Jonathan Schroden, Alexander Powell, David Knoll, and Larry Lewis, Adaptive and Innovative: An Analysis of ISIL's Tactics in Iraq and Syria, CNA, Dec. 2015.

[54] John Hanley and Mark Mandales, Adapting to a New Era: The SSG's Transition to an Innovation Cell, CNA, Nov. 2018.

[55] Michael Markowitz, Peter Perla, Albert Nofi, and Christopher Weuk, SEAPOWERS: A Game of Naval Technology Innovation 1875–1920, CNA, Dec. 2001.

[56] Alex Powell, DOD Innovation Office memo, CNA, Sep. 2019.

[57] Ciro Lopez and Bradley Dickey, Practicing Innovation: An Analysis of the 2015 USS *Preble* Deployment, CNA, Aug. 2016.

- Evaluated through metrics that measure the capability provided to the warfighter, not just papers moved or dollars spent[58]
- One way to achieve “transformation”[59]
- The “intersection of alignment and action; skills, knowledge, competencies; and cross-cultural learning”[60]
- “Disruptive change.”[61]

What points can be taken from these definitions and descriptions? The definitions point to several features regarding innovation. All involve change: doing something differently. Two specifically acknowledge different kinds of innovation, some involving technology but others representing changes in processes (e.g., tactics). One talks about taking an invention and running with it, having a technology focus.

The descriptions confirm some of these definitional aspects as well as provide additional nuance regarding innovation:

- Innovation combines technology with new approaches and processes.
- Innovation is not just about change but a new capability being created.
- Innovation involves transformation or disruptive change: more than a small, incremental change, something fundamental is being altered.

Overall we see a contrast between the DOD organizational focus—with a preponderance of its efforts focused on technology acquisition—and the common features of CNA descriptions of innovation that includes the importance of non-materiel contributions and provision of capabilities. Furthermore, there is a difference in scale: DOD efforts such as DIU and DDS are often focused on quick wins that can be achieved in the near term, while some CNA descriptions point to innovation being disruptive and having significant impact in the bigger picture. With these different perspectives, we now look to academic treatments of military innovation seeking additional clarity on what the U.S. goal should be from a NDS perspective.

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58 Thomas Neuberger, USJFCOM: Strategic Planning Council, CNA, May 2001.

59 H.H. Gaffrey, W. Eugene Cobble, Dmitry Gorenburg, and Michael McDevitt, The American Way of War and its Transformation in the Post-Cold War Period: 1989–2003, CNA, Feb. 2004.

60 Mitzi Wertheim, Learning a Winning Strategy: Changing Organizational DNA, CNA, Jun. 2005.

61 Diane Vavrichek, Larry Lewis, Claire Noble, Colin Shields, and Anna Williams, Analyzing the Autonomy Ecosystem, CNA, Oct. 2019.

Academic Definitions

The literature regarding military innovation is robust and growing. However, it lacks consensus on how innovation should be defined, and that is acknowledged within the field:

- "Authors in the field have proposed a tangle of orthogonal, even contradictory, definitions over the past 20 years."[62]
- "There are almost as many definitions of military innovation as there are studies in the military innovation literature."[63]

While there is no common definition, there are several common attributes that individual definitions tend to include: a significant change, an operational practice, military effectiveness, and whether the innovation was successful. We discuss each attribute in turn.

An Idea about Change

A common feature of academic definitions of military innovation is that they involve significant change. For example:

- "A major change"[64]
- "A significant development in military thought"[65]
- "A change in the goals, actual strategies, and/or structure of a military organization."[66]

This is consistent with the CNA definition of innovation shared above: "Doing something differently than the way it is currently done."[67]

Some have added descriptive terms to emphasize the major scale of the changes involved. For example, Williamson Murray uses the term "revolutionary innovation," which requires "one particular individual's capacity to guide the path of innovation for a short period of time,"

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62 Adam Grissom, "The Future of Military Innovation Studies," *The Journal of Strategic Studies* 29(5) (2006).

63 Michael C. Horowitz and Shira E. Pindyck, What is a Military Innovation? 2019.

64 Theo Farrell, "Improving in War: Military Adaptation and the British in Helmand Province, Afghanistan, 2006–2009," *The Journal of Strategic Studies* 33(4) (2010).

65 Itai Brun and Carmit Valensi, The Revolution in Military Affairs of the "Other Side," Contemporary Military Innovation: Between Anticipation and Adaptation, Routledge, 2012.

66 Theo Farrell and Terry Terriff, eds., The Sources of Military Change: Culture, Politics, Technology, Making Sense of Global Security, Lynne Rienner Publishers, 2002.

67 Framework for MCWL Experiments, CNA, Mar. 20, 2003.

emphasizing that this innovation is not simply the result of the military institution sustaining what it has already been doing.[68]

Results in Institutional Change

Another feature of academic definitions is that it entails a major change to the military as an institution. For example:

- "A major change that is institutionalized in new doctrine, a new organizational structure and/or a new technology"[69]
- "A major restructuring of military organizations, significant changes in strategy, or both."[70]
- "[a change requiring] a military service destroy or thoroughly redirect an important part of itself."[71]
- "A change in the goals, actual strategies, and/or structure of a military organization."[72]

Institutional Change versus Adaptation

Farrell notes that innovation can be distinctive from operational adaptation, where changes are made in the midst of an operation in response to an urgent requirement. Farrell defines adaptation as "change to strategy, force generation, and/or military plans and operation that is undertaken in response to operational challenges and campaign pressures."[73] But these adaptations need not result in institutional change; rather, they can be changes that the military force then discards after the course of the operation. Military leaders recognize that successful adaptation is critical for successful military operations; for example: GEN Petraeus described how it is "incumbent on us to assess the situation continually and to adjust our plans, operations, and tactics as required."[74] Examples of such adaptation include changes made in

68 Williamson Murray, Military Adaptation in War: With Fear of Change, Cambridge University Press, 2011.

69 Theo Farrell, "Improving in War," 2010.

70 Matthew A. Evangelista, Innovation and the Arms Race: How the United States and the Soviet Union Develop New Military Technologies, Princeton University Press, 1988.

71 Owen R. Cote, The Politics of Innovative Military Doctrine: The U.S. Navy and Fleet Ballistic Missiles, Massachusetts Institute of Technology, PhD dissertation, 1996.

72 Theo Farrell and Terry Terriff, The Sources of Military Change, 2002.

73 Theo Farrell, "Military Adaptation in War," in Military Adaptation in the Afghanistan War, eds. Theo Farrell, Frans Osinga, and James Russell, Stanford University Press, 2013.

74 General David Petraeus, Remarks on the Future of the Alliance and the Mission in Afghanistan, 45th Munich Security Conference, delivered Feb. 8, 2009.

Iraq and Afghanistan to promote more effective counterinsurgency operations—such as the formation of Human Terrain Teams, the Force Strategic Engagement Cell, and the COIN Academy; the creation of intelligence fusion cells that developed new tactics for targeting high-value individuals; the development of new counterinsurgency doctrine (Field Manual 3-24); and equipment created specifically for the challenges of counterinsurgency, including mine-resistant armored vehicles and electronic countermeasures to deal with the threat of improvised explosive devices. Of all of these steps, only the doctrinal development was preserved as an institutional change in the U.S. military, but all of these measures contributed to adaptation in the midst of those operations.

Operational Practice

Another common attribute of academic definitions is that the focus of military innovation is changing operational practice. For example, Rosen described innovation as something inherently linked to combat functions, where the military organization approaches warfighting in a fundamentally different way than what the institution has done in the past: "It involves a change in one of the primary combat arms of a service in the way it fights or alternately, the creation of a new combat arm…. changes in the formal doctrine of a military organization that leave the essential workings of that organization unaltered do not count as an innovation."[75]

Others, such as Zisk, have echoed this point that military innovation is focused on warfighting: "a major change in how military planners conceptualize and prepare for future war."[76] Pierce also explicitly tied innovation to operational practice, coining the term "disruptive innovation" to emphasize the major scale of the change involved and defining it as "an improved performance along a warfighting trajectory that traditionally has not been valued."[77]

Military Effectiveness

Military innovation in the academic literature is not just about being more efficient, for example, saving labor or time. A number of researchers make an explicit tie between military innovation and improved operational effectiveness. Jungdahl and MacDonald define innovation as a change that creates "an improvement in overall military effectiveness."[78]

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[75] Stephen P. Rosen, Winning the Next War: Innovation and the Modern Military, Cornell University Press, 1994.

[76] Kimberly M. Zisk, Engaging the Enemy: Organizational Theory and Soviet Military Innovation 1955–1991, Princeton University Press, 1993.

[77] Terry Pierce, Warfighting and Disruptive Technologies, 2004.

[78] Adam M. Jungdahl and Julia M. Macdonald, "Innovation Inhibitors in War: Overcoming Obstacles in the Pursuit of Military Effectiveness," *Journal of Strategic Studies* 38(4) (2014): 467–499.

Likewise, McIntire describes innovation as a combination of novel technology and doctrinal and organizational changes that collectively “create a revolutionary effect” on military operational effectiveness.[79]

Griffin discusses how innovation is incentivized when militaries have a clear and pressing need for improved military effectiveness: “There is a natural tendency for military organisations to pay the most attention to the dynamics of innovation when they either perceive themselves ill-prepared for an imminent threat or ill-suited to cope with an existing one: basically, when the character of a given conflict makes them feel most vulnerable.”[80]

Several in the academic literature have noted the field’s tendency to define innovation in terms of its successes: that innovation only counts as innovation if the change leads to better battlefield results. This tends to cloud the definitional purity of the concept of innovation, as the innovation may potentially result in improved military effectiveness in other contexts but the particular conditions and/or applications were not well suited for the change in that particular case.[81] Thus for our working definition, we will include “potential” to allow for such context-dependent variables.

Working Definition

With these common elements defined, we can create a simple notional definition of innovation that captures them:

> *Military innovation is a significant change in an organization and its operational practice potentially resulting in greater military effectiveness.*

This functional definition is more or less consistent with the attributes of innovation from CNA products, but is distinctive in that it has a focus on warfighting. This definition also stands out from current DOD initiatives as it is more holistic than the DOD’s largely technology focus, and it is more focused on major changes, as opposed to immediate impact through rapid acquisition. At the same time, we see that this definition seems to fit the goals the NDS has for innovation: helping the U.S. to prevail in a competition with peer competitors in an era where historical advantages have eroded.

[79] David Harrison McIntyre, Taming the Electric Chameleon: War, Offense-Defense Theory, and the Revolution in Military Affairs, University of Maryland-College Park, PhD dissertation, 1999.

[80] Stuart Griffin, “Military Innovation Studies: Multidisciplinary or Lacking Discipline?,” *The Journal of Strategic Studies* 40(1–2) (2017).

[81] See, for example, Michael C. Horowitz and Shira E. Pindyck, What is a Military Innovation?, 2019; Adam Grissom, “The Future of Military Innovation Studies,” 2006.

With this definition of innovation in hand, in the next section we consider a number of real-world cases of innovation to better understand the factors that can influence the likelihood of successful innovation.

Innovation Close Up: Military Examples

In the previous section we consider different definitions of innovation to help us to better understand necessary steps to promote successful innovation. In order to identify factors that tend to encourage—or discourage—innovation, it can also be helpful to consider practical examples of military innovation, both historical and contemporary.

Historical examples

First we examine four examples of innovation from past military operations: the U.S. Marine Corps development of amphibious warfare; the introduction of helicopters in amphibious operations in light of the threat of nuclear weapons; Germany's development of military aircraft using jet engines during WWII; the U.S. Navy's development of fighter aircraft, leveraging that earlier invention of jet engines.

Amphibious operations

From its inception the U.S. Marine Corps has been responsible for security for the Navy, guarding ships and naval installations. Over time, they also garnered a second mission, small wars. In 1894, Congress directed a third mission for the Marine Corps: defending forward-based naval bases. Just a few years later, in the aftermath of the Spanish-American war, this mission became more urgent as the U.S. found itself a new colonial power with new responsibilities, including holding and protecting additional forward bases, such as the Philippines. In 1900, the Navy's General Board recommended the Marine Corps to commit to that role, and the Secretary of the Navy directed the Marines to create a unit for this purpose. The Marine Corps did create a battalion for forward base defense and had them conduct an exercise in 1901 to practice an unopposed landing on an island close to Puerto Rico. However, besides the creation of the unit, Marine Corps doctrine, organization, or overall mission priorities did not change.

In 1909, the General Board tried to move the Marines towards this mission, directing that forward base defense should be the main mission of the service. In 2010, Commandant George Elliot provided SECNAV with a proposed course of instruction for forward base defense, but no actions were taken as a result. In 1914, the General Board requested the Marines begin coursework on that subject as well as hold annual exercises. However, these recommendations were not heeded in light of Marine operational requirements in locations such as Mexico, France, and Haiti.

During World War I, in 1915, Col Lejeune created an "ad hoc war committee" with three thoughtful captains: Ralph Keyser, Pete Ellis, and Thomas Holcomb (later a commandant), examining future threats and ramifications to the Marine Corps. Around the same time, Lejeune, Holcolme, and Bill Russell established the Marine Corps Association (MCA) and its publication, *The Marine Corps Gazette*. Expressing frustration with Marine Corps leadership and its continued focus on the mission of guarding ships and installations, the group and publication called for the Marines to embrace forward base defense and amphibious operations as its new mission.

When General Lejeune became Commandant of the Marine Corps, he made several moves to advance that mission within the Marines. Within the Marine Corps General Staff, Lejeune created a new plans section within the Directorate of Operations and Training, with Pete Ellis from the "ad hoc war committee" the intellectual leader of the group. With the support of Lejeune and other senior leaders, Ellis produced two important intellectual works on amphibious operations in 1921: "Advance Base Operations in Micronesia" and "Navy Bases: their Location, Resources, and Security." Ellis' work served as the intellectual foundation for the eventual Marine mission of amphibious operations.

But while Lejeune embraced some aspects of that work, such as including elements of Ellis' publications in war planning, in other ways he took actions that discouraged the new mission from taking full hold within the Marines. For example, Bill Russell, co-founder of the MCA and *Gazette*, led the officer promotion board in 1920 after World War II. Wanting to create a group of leaders embracing amphibious operations versus ideas from the last war, Russell built in promotion criteria that favored new intellectual thinking. But those board results were overturned by Lejeune, who instead incentivized operational experiences and reinforced existing views about the Marine Corps mission. While Lejeune was responsible for building the intellectual foundation for amphibious operations, he did not take the additional steps necessary to institutionalize them within in the Marine Corps.

Progress began in earnest in the 1930s. The next Commandant, General Fuller, selected Brig Gen Randolph Berkeley to command Marine Corps schools in 1930. Brig Gen Berkeley created a group to start work on doctrine for Marine Corps Landing Operations. However, this work also emphasized the small wars mission, showing the difficulty of the Marines embracing amphibious warfare as its primary mission. In 1932, Berkeley's replacement, Brig Gen James Breckenridge, refocused Marine Corps schools on landing operations. Every incoming student in the 1932–33 school year was required to study the British history and lessons learned of the Gallipoli operation, and the school focused on material and organizational requirements for that mission. They concluded that a significant restructuring of the Marine Corps was needed.

The opportunity for such a change came the following year. In 1933, the Chief of Staff of the Army, General Douglas MacArthur, proposed that the Marines be transferred to the Army. While similar ideas had been voiced before, the considerable influence of MacArthur made this a threat that Marine leadership took seriously. The Commandant, General Ben Fuller, trusted his Assistant Commandant, General Russell, and gave him freedom to develop a counter-proposal to advocate the value of the Marines as a separate service. That was the opportunity Russell had been looking for. He proposed the creation of the Fleet Marine Force, a broad reorganization to enable the Marines to better support the Navy and its needs for protected forward bases, including the mission of amphibious operations. This move laid the groundwork for the Marine Corps to make sweeping institutional changes to execute that mission.

When General Russell became the next Commandant in 1934, he took steps to make further changes to realize operational capabilities for amphibious operations. This included changing the emphasis in Marine schoolhouses, which had historically promoted land operations from World War I as the key mission. Russell tasked Breckinridge, still commanding the Marines' schools, to continue his efforts promoting the amphibious warfare mission and specifically to support the Fleet Marine Force (FMF) concept. The immediate result was the publication of doctrine, the 1934 Tentative Manual for Landing Operations. In 1935, the Marines began exercising FMF landings annually, a practice that continued until interrupted by World War II.

While the Marines were reorganizing and developing doctrine, training, and education to support amphibious warfare, they still did not have the technology to support the concept: specifically, ships well suited to the amphibious mission. Accordingly, Commandant Russell also created a board to look into materiel requirements for amphibious warfare, the Marine Corps Equipment Board. This board, operating for several years, failed to supply the necessary invention; this invention instead came through serendipity from then Lieutenant Victor Krulak. Stationed in China in 1937, he happened to observe a Japanese vessel conducting a landing. He sketched the unusual hull design and sent a report back to the Bureau of Ships. The report was not acted on and was labeled with a note: "some nut out in China." Finally, Krulak retrieved his report and showed it to others. In 1941, a copy of his pictures and report made it to a civilian boat company, which made a vessel in accordance with that design. That vessel became the Landing Craft Vehicle, Personnel (LCVP), which was used extensively in World War II.

The end result of the extensive work in the 1930s to develop amphibious warfare was seen in a mature capability to conduct offensive amphibious assault by the end of World War II, including the taking of Iwo Jima. While the mission was first realized as a requirement 50 years before, it took decades to get the service as an institution to take the steps necessary to make that mission a reality. When a leader dedicated to making institutional changes was in place, the necessary changes could take place in just a fraction of that total time—just over a decade.[82]

Helicopters in amphibious operations

The Marine Corps first began considering the use of the helicopter as an integral part of amphibious operations in the aftermath of the atomic bomb test in 1946 in the Bikini islands. The explosive power and destruction displayed in that test was so severe that Army leadership began openly discussing the Army taking over the Marine Corps, since the feasibility of a conventional amphibious assault against an adversary with nuclear weapons was called into question.

The Marine Corps senior observer to the Bikini tests, LtGen Roy Geiger, wrote a report arguing that the possibility of nuclear weapons necessitated that the USMC reconsider its approach to amphibious warfare, shifting to the use of either air platforms or submarines to reduce the impact of nuclear weapons on the amphibious force. In response to Geiger's report, USMC Commandant Alexander Vaudegrift created a board to study options for a new way of amphibious warfighting in the age of nuclear weapons. A key consideration was the problem of the need for improved mobility. The board, established in 1946, was led by MajGen Lemuel Shepherd. The Shepherd board reported back to the Commandant that helicopters were the best solution to the mobility problem and were key to the future of amphibious warfare.

The results of the Shepherd board led to two parallel and complementary actions. First, the Helicopter and Seaplane Board was established at the Marine Corps Schools. The board, officially led by Col Robert Hogaboom, was charged with doctrinal development for the use of helicopters in amphibious warfare. In practice, Col Hogaboom was busy with other responsibilities, so the practical efforts on doctrine development was led by LtCol Victor Krulak (who had earlier been called a "nut in China").

Second, in early 1947 the USMC established Marine Helicopter Squadron one (HMX-1), under the command of Col Ed Dyer (one of the three colonels serving as a secretariat for the Shepherd board). The squadron was located at Quantico, in proximity to the Helicopter and Seaplane Board, so that it could interact with the doctrinal development process. It is notable that the squadron did not have its first aircraft delivered until early 1948, but the squadron was involved in doctrinal development and busy with organizational tasks to prepare themselves for when aircraft were available. In 1948, Col Dyer and LtCol Krulak co-developed the first

[82] This example is based on several sources: Terry Pierce, Warfighting and Disruptive Technologies, 2004; Major John L. Gallagher IV, Complexity Leadership Theory: A United States Marine Corps Historical Overlay, School of Advanced Military Studies, United States Army Command and General Staff, College Fort Leavenworth, Kansas, 2017; and Leo J. Daugherty III, Pioneers of Amphibious Warfare, 1898–1945: Profiles of Fourteen American Military Strategists, McFarland, 2009.

USMC doctrinal publication on the use of helicopters: Amphibious Operations, Employment of Helicopters (Tentative).

In 1950, LtCol Keith McCutcheon assumed command of HMX-1, right when the Korean war began. HMX-1 was deployed to Korea, and LtCol McCutcheon was involved in many new uses of helicopters in warfare. Reports on operational deployments and lessons learned were sent back to Quantico for their incorporation into concepts and doctrine. In 1955, the Marines issued Landing Force Bulletin 17, which included a complete rewrite of existing doctrine regarding amphibious operations, focusing on helicopters conducting air assault.

The next step of institutionalizing this new way of warfighting focused on reorganizing the Marine Corps. To that end, in 1956 Commandant Randolph Pete established the Hogaboom Board, also known as the Fleet Marine Force Organization and Composition Board. The board was a detailed examination of "the current organizations, the organizational thinking, and in the thinking of the Marine Corps in general." In their mandate, they were to identify parts of the Marine Corps organization that were incompatible with this new way of warfighting, as well as preconceptions within the force that were incorrect. Completed in December 1957, the board recommended broad changes to almost all of the Marine Corps forces, making them mobile by air. These changes were largely made over the next few years, institutionalizing the operational adaptations of the previous few years.[83]

In just a bit over 10 years, the service developed and then reorganized itself for a new form of amphibious warfare. In their pursuit of the use of helicopters in amphibious operations, the Marines were far ahead of the Army in their experimentation and operational use. The Air Force, newly responsible for supporting the Army's aviation needs, was not interested in a platform that was low and slow, and the Army wanted to replicate the mechanized and armored approach it used in World War II. Only the Marines saw the promise of the helicopter in warfare, in part because they were looking for a solution for a critical problem for the force. It is likely no accident that this innovation was linked to the continuing survival of the Marine Corps as a service, being threatened with being absorbed by the Army if the amphibious mission were to disappear. Notably, in the development of this innovation, the technology was not ready when the USMC began, but the USMC pursued the technology in parallel with the supporting ecosystem.[84]

[83] We note that HMX-1 survives to this day as the Marine helicopter squadron that provides transport to the President of the United States, Marine One.

[84] This example is based on several sources: Terry Pierce, Warfighting and Disruptive Technologies, 2004; LtCol Eugene Rawlins, Marines and Helicopters: 1946–1962, History and Museums Division, Headquarters, U.S. Marine Corps, 1976; and Major John L. Gallagher IV, Complexity Leadership Theory, 2017.

Germany's development of jet aircraft

Following World War I, it became clear to world powers that technological innovation would be needed to surmount the limitations—particularly that of speed—of propeller-driven aircraft. Germany, Great Britain, Italy, Japan, the Soviets, and the U.S. in particular pursued various types of reaction engines to address this need. At this time, however, the U.S. trailed behind European powers in aeronautics. It had not designed or developed any of the fighter aircraft it used in combat in WWI and had only subsequently begun developing such indigenous capabilities, while initially continuing to rely on other nations for basic aeronautical research and major technological advances.

The jet engine was developed independently in the 1930s by the Royal Air Force's Frank Whittle in the UK and German physicist Hans von Ohain. Yet there were many technical challenges to overcome in order to operationalize these concepts, especially for the heavy demands that emerged during World War II. Challenges included obtaining sufficient quantities of heat resistant material with which to build the aircraft, designing the aircraft body to support such a heavy engine, and even developing ejection seat technology. (In conventional fighter aircraft, pilots could bail out by merely climbing out of the cockpit and jumping clear of the aircraft—a tactic that the speed and mechanics of the jet rendered infeasible.)

Germany won the jet race with the Me 262, an aircraft that was used as both a bomber and a fighter. Initial development of the aircraft began before the war, and it made its first flight in 1942. But technical challenges with mass production of the jet engine kept the jet from entering the war until the summer of 1944. The Me262 saw notable success in the final year of the war—reportedly having shot down 452 Allied aircraft with only 100 Me 262s lost.[85] While the aircraft was superior to Allied aircraft in performance, by that time the war was one of attrition and defense of German territory. Thus, the advantages of the Me 262, while possibly decisive if available earlier in the conflict, were characterized by historians as "too little, too late" to change the course of the war for the Germans.[86]

Why did the Germans succeed in developing and operationalizing the jet aircraft ahead of the other world powers? One major factor is likely to have been Germany's prioritization of the effort in the face of a challenging fiscal environment. Investing in aviation technology would have presented fiscal risk at any time, but a key portion of Germany's investment took place

[85] "76 years ago, the first jet fighter changed aerial combat forever, but it didn't do Hitler any good," by Benjamin Brimelow, *Business Insider*, Jul. 22, 2020, https://www.businessinsider.com/nazi-germany-me-262-jet-fighter-changed-aerial-combat-2020-7.

[86] See, for instance, Colin D. Heaton and Anne-Marie Lewis, "Too Little, Too Late: Hitler and the Introduction of the Messerschmitt Me 262," *The History Reader*, Dec. 8, 2012, https://www.thehistoryreader.com/military-history/little-late-hitler-introduction-messerschmitt-262/.

during the Great Depression, when the liquidity of all global powers was severely limited. One factor that enabled such investment—and would have been particularly controversial at such a time—was Germany's authoritarian system of government, which allowed Nazi leadership to fund its priorities without having to compromise with other government bodies. (The USSR and Japan—also authoritarian regimes working to develop jet technology at this time—faced political hindrances as well as the consequences of Stalin's purges and limited natural resources in Japan.)

Germany continued to prioritize jet development during the war, developing and experimenting with not only jet aircraft but also a number of other radical aeronautical and propulsion concepts. For example, in addition to the Me 262, the Germans deployed a rocket-powered aircraft (the Me 163) and a jet bomber (the Ar 234) during the war, and they were simultaneously developing experimental concepts such as bombers with forward-swept wings, vertically-launched rocket interceptors, and flying wings. Judging by these efforts, the Nazis embraced experimentation and the associated risk of failure and seem to have maintained a supportive environment for the engineers doing this work.

Jets were not regarded as an operational imperative to the same degree for the Americans as they were for the Germans. The U.S. focused instead on producing conventional aircraft on a large scale. And, late in the war, when the Germans required homeland defense weapons with increasing urgency, the greatest American aviation need was for aircraft that could escort bombers—a mission that required longer range than jets at the time could support. (The Americans did not ignore the need for jet development, however; the U.S. worked to develop several jets during the war—such as Bell Aircraft's XP-59 (which was built under a British license) and Lockheed's P-80—but none were completed in time to be fielded in combat.)

German jet innovation was also aided by an organizational development, namely, the establishment of the Ministry of Aviation—the Reichsluftfahrtministerium, or RLM—in 1933, which was focused on the development and production of German aircraft. The RLM provided a centralized hub where ideas could be submitted and was able to foster efficiencies and coordination that contributed to the Germans' success in the development of jet technology.

Although the Germans won the race to develop jet aircraft, this success did not help them to prevail in the war. Hence the factors that led to the Germans' technological success—including prioritizing aeronautical innovation during the Depression and the war—were not sufficient in themselves for strategic success.[87] Observers have discussed the propensity of military

[87] This example draws on the following references: Mark A. Lorell and Hugh P. Levaux, The Cutting Edge: A Half Century of U.S. Fighter Aircraft R&D, RAND, 1998, https://www.rand.org/content/dam/rand/pubs/monograph_reports/1998/MR939.pdf; Colin D. Heaton and Anne-Marie Lewis, "Too Little, Too Late," 2012; Benjamin Brimelow, "76 years ago, the first jet fighter changed

leaders to believe that technology and technical superiority is sufficient for military success, which is clearly seen here to not be the case. The persistence of this false belief over time, and its inability to be killed, led LTG McMasters to call this belief the "Vampire Fallacy."[88] We discuss this more in the later section, Putting Innovation into Practice.

The Navy's adoption of jets

The U.S. had been working to develop jets before and during the war, but the Navy was more hesitant than the Air Force to pursue jet technology due to concerns about the suitability of jets for aircraft carrier-based operations, with challenges including jets' substantial fuel requirements and low power on takeoff. The Navy initially relied on "second string" companies to develop the technology because of the effort's lower priority to the Navy overall, because the Navy's lead contractor, Grumman, was overwhelmed with wartime production needs, and also because the Navy thought that newer companies might be more innovative in developing the new technology.

The significant advantages of the Axis jets over Allied propeller aircraft during the final year of World War II confirmed the operational imperative for such technology. Following the war, both the Americans and the Soviets sought to learn lessons and technological details from Germany: for example, both raided jets from Germany to study. The U.S. did acquire one unique asset from Nazi Germany: Hans von Ohain, the developer of Germany's first turbojet, was brought to the U.S. after the war, where he worked for several decades as a scientist for the Air Force and helped the U.S. military learn from the German experience.

Both the Soviets and the U.S. Air Force moved aggressively to develop jet technology as the Cold War began, seeking a competitive edge. The Navy moved more slowly, but it felt pressure to develop this capability after the Air Force claimed the combination of nuclear weapons and their long-range bombers made naval aviation obsolete. When the Secretary of the Navy cancelled the construction of an aircraft carrier in 1949, the Navy responded by developing jet aircraft to show the continuing relevance of naval aviation.

The Navy sought to expedite its development efforts, expediting them by embracing risk in a variety of ways. The Navy contracted with multiple companies simultaneously to create parallel efforts develop jets in order to increase the odds of success. It also ordered the production of some jet models before flight testing was completed in order to accelerate the process and accept risk. In addition, jets were sent into combat in the Korean war while the

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aerial combat forever, 2020; Bruce D. Callander, "The Jet Generations," *Air Force Magazine*, Oct. 1, 2002, https://www.airforcemag.com/article/1002jets/.

[88] LTG H.R. McMaster, "Continuity and Change: The Army Operating Concept and Clear Thinking about Future War," *Military Review*, Mar.–Apr. 2015.

Navy was still learning how to operate safely with the platforms. Operating the jets off of aircraft carriers presented a significant challenge, as anticipated. The Navy also began to conduct nighttime and all-weather carrier flight operations during this time, representing a further difficulty for the Navy's jet operations.

For these reasons, as well as due to other technical challenges that jet technology presented, the Navy lost many jets and aircrew. The overall rate of loss of Navy aircraft (of all types) and aircrew during the period of the adoption of the jet was staggering: from 1949, the year that significant numbers of jets arrived at the fleet, until 1988, the year when the Navy's mishap rate finally matched that of the Air Force, the Navy and Marine Corps lost almost 12,000 aircraft and over 8,500 aircrew. The F-8 Crusader, a supersonic fighter introduced to the fleet in 1957, may be the most egregious example: of the 1,261 F-8s produced, over 1,100 were involved in mishaps.

What the Navy required in order to safely and successfully adopt jets—in addition to technological advancements—was institutional change. While the Air Force made needed institutional adjustments swiftly, aspects of Navy culture hindered change. Indeed, naval aviation had been rife with risk even before the jet age and had developed a daredevil culture. This resulted in some intransigence against the adoption of stricter safety and training measures, which were needed with the more demanding standards and higher risks with jet platforms. The Navy's culture of delegation and independence enshrined in the concept of mission command also may have slowed institutional change. And while inter-service rivalry was a driver for innovation in the introduction of helicopters in amphibious operations, as discussed above, here it may have delayed progress, since the Navy may have been averse to following the Air Force's lead.

The institutional changes the Navy eventually made that led to the successful integration of jets into the force included more structured training programs and pilot performance evaluations. In addition, introduction of jet aircraft prompted further steps for professionalization and safety such as stronger accident investigation techniques, providing formal training for squadron safety officers, and establishing the flight surgeon role. The Navy also created detailed reference manuals and started publishing a safety magazine that featured articles focused on describing accidents and near misses. During this period of transition, the Navy Fighter Weapons School, also known as TOPGUN, was established in order to learn lessons from the poor performance of Navy fighter jets in Vietnam. Since its inception, TOPGUN has been highly successful in its fostering of tactical excellence and innovation and has become a model that the other naval warfare areas seek to emulate.

The Navy's transition to jet aircraft was a major innovation enabled by an aggressive approach to research and development as well as far-reaching institutional changes to training and learning. Although the delays that occurred in making the needed institutional changes came at a high cost to the Navy, this innovation was, in the end, quite successful and a critical one for the Navy.[89]

Contemporary examples

Next we consider two contemporary examples of innovation. The first example is the move to network-centric operations in air defense, as manifested in Operation Iraqi Freedom in 2003. The second example is a Navy ship, describing the process it created and its determination to encourage innovation during its deployment. This example, while not ending in a decisive, radical change to operations, helps illustrate the creation of an environment that fosters innovation at a unit level.

Network-Centric Operations in Air Defense

In the 1970s, U.S. defense officials were faced with the potential threat of a Soviet conventional-force invasion of central Europe. Soviet forces had a great advantage in force size, up to three times what U.S. and NATO forces had available in terms of personnel and armored vehicles. The U.S. and its allies were unable to muster sufficient numbers to counter the strength of the Soviet force directly. The U.S. saw advancements in microelectronics and computers as an opportunity to create an offset: improving conventional capabilities and creating an asymmetric advantage to counter the Soviet's numerical edge. This advantage consisted of using advanced technology to enable better information on the battlefield and develop the ability to conduct precision strikes in order to improve combat effectiveness.

This initiative, known as the Second Offset, was not simply a broad effort to generally improve all weapon systems through better technology. Rather, it identified specific enabling capabilities for particular operational requirements and pursued their development over the course of decades. In 1991, Operation Desert Storm displayed the initial results of the Second Offset efforts. Desert Storm was seen as a sweeping success and was touted as the new American way of war. In particular, three advanced technology components of the Second Offset contributed to Desert Storm's success: reconnaissance, situational awareness, and integrated action; suppression of enemy defenses; and precision-guided munitions. Collectively, these capabilities—and a well-led, well-trained force using them—resulted in a

[89] This example is based primarily on the following reference: Robert C. Rubel, "The U.S. Navy's Transition to Jets," *Naval War College Review* 63(2) (2010), https://digital-commons.usnwc.edu/nwc-review/vol63/iss2/6/. We have also drawn from Bruce D. Callander, "The Jet Generations," 2002; and Mark A. Lorell and Hugh P. Levaux, The Cutting Edge, 1998.

decisive victory marked with a rapid end, minimal Coalition casualties, and sharply reduced civilian casualties compared to previous armed conflicts.[90]

However, this progress was not complete. One of the operating concepts driving this development was network-centric operations, where different military surveillance and weapon systems were connected and shared information, with the mutual contributions more effective than the individual parts. In the air and missile defense mission of Desert Storm, this ideal was not met. Problems with connectivity and interoperability forced an approach where systems largely relied on their own surveillance contributions, and operating areas for fighter aircraft and missile defense systems were kept apart because of deconfliction challenges and fratricide concerns.[91]

After Desert Storm, there was strong interest in having the services able to function as a joint force and better meet the concept of network-centric operations, with multiple platforms operating in the same areas and fusing their individual contributions for a more complete surveillance picture. This impetus was strengthened by the fact that 24 percent of U.S. casualties in Desert Storm were caused by friendly fire, where important information about friendly forces was not passed as needed.[92] This resulted in the creation of the Joint Air Defense Operations Joint Engagement Zone Joint Test and Evaluation Activity, which pushed capabilities and tactics to promote the ability of air defense systems to work together in a seamless battlespace. This activity was institutionalized as the All-Service Combat Identification Evaluation Team, and its activities expanded to also cover ground operations and time-sensitive targeting and close air support.[93]

These activities held annual events where the different services brought air defense assets to exercise together: including the Army's PATRIOT; the Marine Corps' TAOC; the Air Force's AWACS, AOC, JSTARS, and F-15 fighters; and the Navy's Aegis ships (CGs and DDGs) and F-14 and F-18 fighters. These systems were integrated together over tactical data links and were instructed to operate and defend against a rigorous opposition force (OPFOR) while experimenting with an integrated, joint approach to surveillance and air defense operations. Unlike many military exercises, these events were highly instrumented (all participants had GPS pods or other means of white cell tracking) and data for each tactical system was collected

[90] These two paragraphs are adapted from Larry Lewis, Insights for the Third Offset: Addressing Challenges of Autonomy and Artificial Intelligence in Military Operations, CNA, Sep. 2017.

[91] Larry Lewis, Insights for the Third Offset, 2017.

[92] Specifically, 35 out of 148 U.S. forces killed in action were due to friendly fire. Mark Thompson, "The Curse of 'Friendly Fire,'" *Time*, Jun. 10, 2014, https://time.com/2854306/the-curse-of-friendly-fire/.

[93] Larry Lewis, Insights for the Third Offset, 2017.

for later analysis. Success was not a matter of operators declaring victory based on their intuition; rather, months of reconstruction and analysis of digital data assessed the level of integration and found the root causes for problems. These root causes were then forwarded to individual System Program Offices when they were issues that system-level changes could solve. Then the fixes could be evaluated in subsequent events. Likewise, tactics and doctrine were developed in parallel to support the joint integration of air defense systems. The integration of in-depth assessments with periodic experimentation created a learning loop that empowered progress.[94]

Due to the efforts of the services and joint initiatives such as this, interoperability challenges observed in Desert Storm were improved significantly, and exercises showed mission effectiveness benefits from this progress.[95] New, network-enabled capabilities and tactics developed during the post-Desert Storm period were used in Operation Iraqi Freedom in 2003. Interoperability deficiencies observed in 1991, such as connectivity issues on the use of the tactical data link Link 11, were improved by moving to the more modern and robust Link 16. We note that while there was clear progress in the 12 years since Desert Storm, it was not perfect—the progress was slow, with many of the deficiencies seen in more recent evaluation events also observed in Operation Iraqi Freedom. For example, in a clear failure of network-centric operations, the Patriot missile system shoot-down of a Navy F/A-18C, several surveillance platforms were reporting different information regarding the aircraft, but that information was never fused in a coherent and accurate picture. Furthermore, as these platforms saw different pictures of what happened, the ability of operators to sort out the true situation was limited.[96] While such deficiencies still existed, the U.S. military had fundamentally changed how it operated in air defense, with doctrinal and technical changes so that military forces could move from a deconfliction approach to a joint integrated approach true to the concept of network-centric operations.[97]

Innovative environment: USS *Preble*

The previous examples described innovations that were developed and cultivated over a decade or more, involving many different units and activities. But innovation can also occur within a single unit, especially when leadership sets the conditions for innovation to flourish. An example of this is the recent deployment of the Navy ship, USS *Preble*. On March 25, 2015,

[94] Ibid.

[95] Ibid.

[96] Larry Lewis, "Improving Joint C2: Lessons from Iraq," presentation at the SMI Network-Centric Warfare Conference, 2008.

[97] Larry Lewis, Insights for the Third Offset, 2017.

USS *Preble* departed Pearl Harbor, Hawaii, for a 7-month independent deployment in the western Pacific Ocean. During the workup and throughout the deployment of USS *Preble*, the leadership and crew deliberately worked to cultivate an environment of innovation. We include this example to show how the general process of innovation can be cultivated within a unit.

While innovation was a leadership focus from the beginning, initially the crew of USS *Preble* did not have a formal process for how to implement their innovation initiative. Many found that lack of structure uncomfortable: the confusion about how to develop and move ideas forward without a proven pathway was a disincentive to participate. In the words of one sailor, "I wasn't going to take the time to suggest a new idea if it was going to end up being thrown down a black hole." However, some members of the crew were not discouraged by this lack of structure and suggested ideas. As these ideas were developed, the processes were codified and matured, and eventually an effective process was established. This approach was documented in ship-wide guidance to encourage all crew members to participate in innovation efforts.[98]

The starting points of the process were several methods to generate ideas. Once an idea arose, there were steps to track, develop, and refine the idea into a promising candidate for an innovative solution. As the concept became more robust, the crew provided resources for experimentation or, when the resources were not available, a theoretical model or at least an in-depth documentation of the idea. When the idea showed promise, the end-result of the process—a successful innovative method or solution to a problem—was then shared with others beyond the USS *Preble*.

This deliberate approach to innovation during the USS *Preble* deployment spawned about 150 novel ideas for how to better solve problems encountered by ships. The innovative ideas were distributed across a variety of ship functions, particularly in warfighting tactics. Not all the innovative ideas were successful, and not all of the promising ideas could be developed further, but about a third to a half of them were considered successes with the potential to change how the Navy operates and fights.

The Navy recognized the leadership and crew of USS *Preble* for the innovation environment and the ideas and methods that they developed. That recognition came in the form of awards and in the effort to further develop and implement the new ideas. Navy leadership has pointed to *Preble*'s example as one for other ships to follow, encouraging innovative thinking and the development of new, more lethal, warfighting tactics.[99]

[98] USS *Preble* (DDG88) Instruction 3910.1, Innovation Awards and Incentive Program, Sep. 29, 2015.

[99] Note that we include a more detailed examination of the USS *Preble*'s innovation efforts in the appendix.

Framework for Promoting Innovation

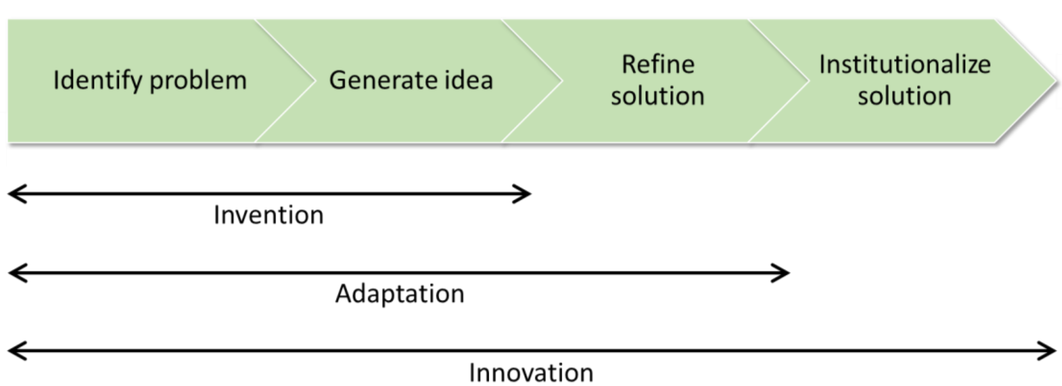
After considering the examples of innovation given in this report, it might be tempting to ask: How do these different examples relate to each other? The examples vary in when they occurred, how long they took to implement, and in the nature of the problems the innovation was intended to address. How do major innovations such as the inclusion of helicopters in amphibious warfare, or the Blitzkrieg doctrine, relate to minor innovations put into place by a single Navy ship? Aren't both the scale and impact of those innovations quite different?

In fact, they all have common features that can help us understand which actions need to be taken for successful innovation to occur. These four steps are:

- **Identify a problem.** What is a key problem facing military forces?
- **Generate an idea.** This could be a way to change in order to solve the problem, a solution not currently part of the military institution (in terms of doctrine, technical capabilities, force structure, etc.)
- **Refine the solution.** Determine whether the idea is feasible and worthwhile, asking: How should it work in practice? How can technology, doctrine, training, and organization work together for greatest effect? This can be explored in experimentation, wargames, or even ongoing operations.
- **Institutionalize the solution.** Codify the refined solution in doctrine, training, systems, etc., resulting in a capability available for future operations.

These key elements of the innovation process are illustrated below.

Figure 2. Key Elements of the Innovation Process



Source: CNA

We also note that some efforts that fall short of innovation (as we have defined it) can still be of value. For example, the process of invention, shown in the figure to consist of an idea generated to help solve an identified problem, can in itself be useful. Perhaps that idea can be retained and then leveraged in the future when the identified problem is more of a priority. Overall, innovation depends on this ability to invent: a receptivity to exploring and trying new ideas. In the end, it is nearly impossible to see where an idea will lead, otherwise experimentation and facing the risk of failure would be unnecessary. Therefore, militaries need to take risks and explore ideas, as we saw in the USS *Preble* example, not knowing if they will be a minor innovation, a major disruptive innovation, or a failure.

Likewise, adaptation is something that military forces often do in the context of operations when faced with operational problems and adversary approaches and capabilities they had not entirely foreseen. As we discussed in the previous section, Farrell has discussed the important role that adaptation can play in achieving military effectiveness.[100] Militaries may reasonably choose not to institutionalize adaptations as they are not prioritized sufficiently to warrant the necessary resources. However, if the adaptation is not institutionalized, and similar problems are encountered again, then the military force runs the risk of having to re-learn lessons.

Such an example of adaptation without institutionalization was seen in Iraq ground operations. In 2004, as U.S. forces began to face an insurgent threat, they began taking significant casualties from IEDs. So, U.S. forces began using checkpoints to help reduce the risk of vehicle-borne IED attacks. U.S. forces created escalation of force procedures to help identify threats and reduce the risk to military forces, but forces found it difficult to distinguish between insurgent vehicle-borne IED threats and innocent civilians driving towards checkpoints. As a result, civilians were misidentified as a threat, leading to a significant number of civilian casualties, including a politically sensitive incident where U.S. forces fired upon and killed the Italian rescuers of a reporter who had been held hostage by insurgents. After a number of operational adjustments, including tracking of civilian casualties, analysis of patterns resulting in civilian harm, and a process to feed lessons back into modified escalation of force procedures, the number of civilian casualties was greatly reduced in 2005 and beyond, showing successful adaptation. However, as operations intensified in Afghanistan, similar problems occurred, with considerable numbers of civilians being killed in checkpoint operations, resulting in criticism of U.S. and international forces from the host nation government as well as international observers.[101] Overall, U.S. forces adapted, but these adaptations were not institutionalized and

[100] Theo Farrell, "Military Adaptation in War," 2013.

[101] Larry Lewis, Reducing and Mitigating Civilian Casualties: Enduring Lessons, JCOA, Joint Staff, Apr. 12, 2013.

transferred from one operation to another. In other words, the lessons from this operational challenge were identified but not learned.

The military innovation literature has debated whether innovation can be top-down (directed by senior leaders) or bottom-up (ideas generated at the working level and resulting in institutional change).[102] While it appears that big ideas can come from anywhere, the critical task of institutionalization is not one that can be decentralized: this involves prioritization and allocation of resources that can only be done at senior levels. So, while the first three steps in innovation can be done at multiple echelons, senior leaders have a special role in the final step of innovation, institutionalizing the solution.

History shows that successful innovation is hard: military forces need to successfully come up with ideas that solve important problems, refine those ideas, and then institutionalize them to achieve the capability that is needed. In the case studies and other examples given here, military forces had to overcome many barriers before innovations were implemented, sometimes delaying the innovation significantly. In the next section, in light of these challenges, we ask: What can the U.S. do to improve its chances of successful and timely innovation?

[102] Stuart Griffin, "Military Innovation Studies," 2017.

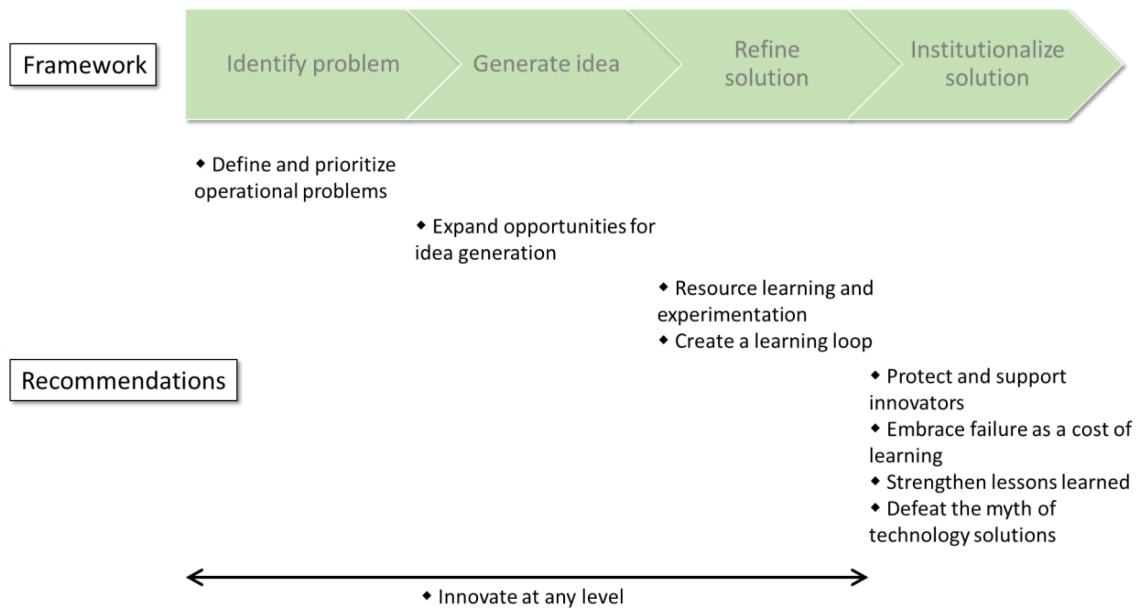
Putting Innovation into Practice

We recall our functional definition of military innovation: "a significant change in an organization and its operational practice potentially resulting in greater military effectiveness." This is fundamentally different from the current DOD innovation enterprise, which we saw is focused primarily on rapid acquisition. Such a focus, while giving marginal improvements over time, will not position the U.S. military to lead in, and better respond to, significant and disruptive change. That is the kind of innovation the 2018 NDS aspires to, what is needed to prevail in a competition against capable, motivated, and well-resourced competitors seeking to find creative offsets to U.S. military superiority. Speeding up acquisition is necessary but not sufficient.

The kind of innovation required to meet the 2018 NDS goals is not easy. Even in the successful cases of innovation given in this report, major changes took at least a decade to achieve, and some took much longer because the different steps were not widely accepted or supported. For example, for amphibious operations, the Marine Corps did not even accept the problem as needing to be solved for several decades. And once efforts began, the process was stuck after idea generation when the service made little effort to refine the solution. Even in the 1930s, when then Col Krulak recognized a critical piece of technology that would enable the warfighting approach, his report was sidelined, and he was described as "a nut." This marginalization slowed the innovation process for years. With rapid advances in commercial technology, and tech sector R&D budgets dwarfing that of entire governments, the luxury of time no longer exists. It is doubtful that the U.S. could afford to take such a leisurely approach to innovation and still successfully compete.

If that is the case, what can be done to improve the chances of rapid and effective innovation? Considering factors from CNA analysis, from analysis of the historical case studies, and reinforced in academic literature, we provide recommendations for strengthening innovation. The recommendations are grouped according to the framework for innovation provided in the previous section, shown in Figure 3.

Figure 3. Recommendations for strengthening innovation



Source: CNA

Define and Prioritize Operational Problems

The first step in the examples of successful innovation is the clear identification and recognition of a pressing problem to be solved. Industry experts have recognized this as a critical step in successful innovation in the private sector as well: there is a need for a great sense of urgency to solve a particular problem.[103] Williamson Murray points out how innovation requires focus on specific problems to be solved: how ideally there will be the "presence of specific military problems the solution of which offered significant advantages to furthering the achievement of national strategy."[104]

To address the need for innovation spelled out in the 2018 NDS, this should be something that senior military leaders should identify for the force: What are the most pressing operational problems that impact U.S. competitiveness? This assessment should consider a combination of strategy, analysis of future trends, assessments of competition's strategy and current and

[103] John Kotter, Leading Change: Why Transformation Efforts Fail, *Harvard Business Review*, May–Jun. 1995.

[104] Williamson Murray, Military Innovation in the Interwar Period, 1996.

future capabilities, and analysis of previous operations. These operational problems can then become a focus for U.S. military innovation efforts overall.

But besides a national strategic focus, this process can also be conducted at other echelons, for specific communities (e.g., for a specific mission or task, to support a regional focus, to support a specific operational plan). The U.S. maintaining a competitive edge will not be a result of simply being innovative in a few key areas, but also maintaining and improving mission effectiveness overall, and this process will help promote such effectiveness.

Expand Opportunities for Idea Generation

Ideas can happen anywhere, and innovation will be fostered by both encouraging and gathering such ideas. Initiatives such as NavalX represent ways to gather new ideas for innovation, and such initiatives can be replicated and decentralized to expand the net for catching ideas. And encouraging new ideas can happen at any echelon. The case studies illustrated that creating small groups and conducting studies were often critical parts of the innovation process. Simply convening small discussion groups, inviting speakers, and maintaining a dialogue can go a long way to better harness the creativity and expertise of individuals in the U.S. military. This can also include conferences to help cross-pollinate ideas across multiple units and commands. Initiatives to encourage and develop new ideas are relatively straightforward and can be inexpensive. This is something the USS *Preble* was able to achieve on its own initiative, with its own resources, but dedicating modest resources to foster idea generation activities would help this to be more sustainable and help the idea sharing process be more effective.

Resource Learning and Innovation for Competitiveness

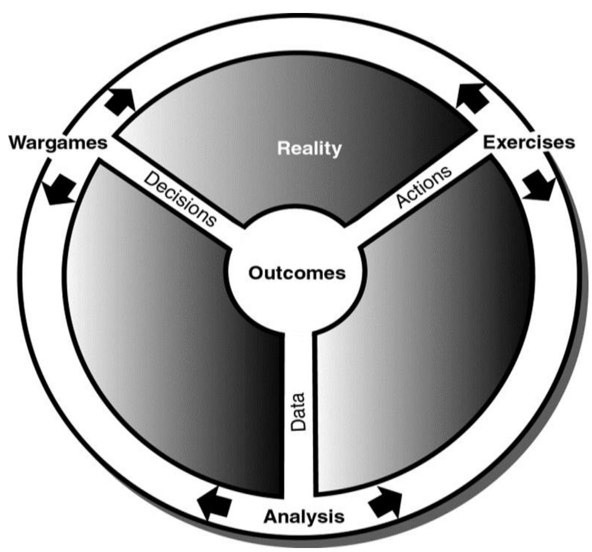
The next step after generating an idea—refining a solution—is more difficult and is more resource-intensive. This step involves efforts to validate the idea, conduct experimentation, run wargames, and couple these activities with robust assessments. This is how the power of an idea becomes a new, innovative operating concept that can then be put into action and result in greater military effectiveness. We note that many experiments today tend to be more technology demonstrations. They may show that something is potentially feasible—helping to generate an idea that can then be further explored—but additional work is needed to better quantify performance and identify strengths, weaknesses, and opportunities for improvement.

While the case studies given here featured such processes for idea generation and refinement, they were ad hoc and the refinement steps in particular can carry significant costs. These steps are unlikely to occur without specifically apportioning resources to them. These assessment and experimentation activities can also be difficult to sustain as they receive scrutiny as military leaders ask whether they are worth it. Perhaps these budgeting decisions would benefit from considering the NDS recipe for success in competition: "A more lethal, resilient, and rapidly innovating Joint Force." How much is spent on lethality? On resiliency? If the 2018 strategy is correct and innovation is an essential component of the U.S. prevailing in a new era of competition, then budgets should support this priority as well.

Create a Learning Loop

Ideas can take considerable work to help translate them into operational art. How does the idea translate into military doctrine; tactics, techniques, and procedures; new training; organizational structures; technology and materiel solutions? Does it really work, and how do we know? Are there unintended effects and how can they be mitigated? How does the idea hold up against a range of possible adversary actions? These are all tasks that need to be addressed in the idea refinement stage, and this is not a linear process. Rather, refinements in doctrine can have repercussions that should be explored and assessed, and likewise, changing technical capabilities that may seem superior should be evaluated to understand any second-order effects. This represents the creation of a learning loop to help refine and improve the idea and bring it to the point where it is ready to be implemented. Historical cases of military innovation tend to feature these learning loops involving experimentation, assessments, and wargames, with this collective approach illustrated below in Figure 4.

Figure 4. Components of a Learning Loop: Experimentation, Assessments, and War Games



Source: CNA

The historical examples of innovation confirm the value of this iterative approach; they also tend to approach the creation of the learning loop in an ad hoc way. But this need not be ad hoc in future innovation efforts. Coupling experimentation with studies/assessments and wargaming should be a standard approach to the most promising and potentially high-impact innovation ideas. This should be facilitated by creating a "learning campaign plan" that sets out activities in experimentation, assessments, and wargames and specifies how they will feed into each other, reinforcing each other for more effective, iterative improvements and refinements. Such a deliberate approach will help accelerate the innovation process as well as make it more effective.

Protect and Support Innovators

The examples in this report also show how innovation is not necessarily an easy task. As Rosen and others discuss, military organizations are incentivized to sustain the status quo as a necessity of running a large organization where failure is not seen as an option.[105] Thus, new ideas can be threatening, and in practice they have often been attacked by organizational antibodies defending what they see as a threat.[106]

In examples where innovation occurred in a shorter timeframe, the practical innovators—those developing concept of operations or doctrine, those spearheading experimentation efforts, those trying to lead those new ideas onto the battlefield—were shielded by higher-level leadership. In some ways that shielding was straightforward, making clear to all that the mission was important and not to be interfered with. In other cases, leaders used deception as a tool to camouflage the radical nature of innovation efforts from those committed to the status quo. Either way, those on the front line of innovation were shielded, their careers were enhanced, and their efforts received recognition when possible.

Embrace Failure as a Cost of Learning

The movie *Apollo 13* describes the credo of NASA as: "Failure is not an option."[107] This was stated in the context of facing the possible death of several astronauts during a space mission. But in other contexts, failure is acceptable and even, in some cases, a desirable outcome. For

[105] Stephen P. Rosen, Winning the Next War, 1994.

[106] An extreme case of commitment to the status quo is embodied in a quote attributed to a U.S. military senior officer during the Vietnam War: "I'll be damned if I permit the United States Army, its institutions, its doctrine and its traditions to be destroyed just to win this lousy war." Brian M. Jenkins, The Unchangeable War, RAND, 1970.

[107] Wikipedia, https://en.wikipedia.org/wiki/Failure_Is_Not_an_Option, accessed Aug. 26, 2020.

example, NASA has a facility at Johnson Space Center where they exposed ceramic tiles to extreme heat in order to see what the threshold was for failure. Understanding failure outside of mission critical contexts is essential to avoid failure in mission critical contexts. Essentially, you need to fail in order to not fail.

The saying "failure is not an option" could also apply to the U.S. military and its mission for preserving national security. In certain contexts, failure would have an unacceptable cost to the nation. This is the imperative that drives the 2018 NDS, that drives the substantial U.S. military budget and the unwavering commitment to the military by the U.S. government overall. An aversion to failure in the U.S. military is understandable, and desirable, in that context.

But the military needs to be careful that the aversion to failure is applied only in the context of those critical missions. In the bigger picture, the U.S. military needs to fail in order to not fail. But in many contexts, failure is both inevitable and desirable.[108] Failure helps to reveal the difference between expectation and reality and illustrates what true capabilities are. Failure also helps forces to recognize and anticipate the warning signs of problems and reduce instances of surprise, which is not something that militaries welcome in warfare. Overall, failure is a valuable tool in learning when it occurs in contexts that are safe and not mission-critical, when the possibility of failure is accompanied by a process for assessment and learning. And when there is broader applicability, lessons from those failures should be shared more widely so that the rest of the institution can benefit from that experience.

Such a process can be instituted to include cases of innovation, documenting not only what worked but also what did not and an assessment of why, allowing others to learn from that experience. Likewise, innovators experiencing failure should be seen as a good sign: a sign that learning is happening and that the military is providing a safe environment for innovation. Thomas Edison, a prolific inventor, had many successes, but he experienced numerous failures along the way. For example, in his development of a new kind of electric battery, "[a]ccording to his close friend Walter S. Mallory, Edison had already tried 9,000 experiments and hadn't yet found a solution. When Mallory commented about the lack of results, Edison promptly responded, 'Results! Why, man, I have gotten lots of results! I know several thousand things that won't work!'" But to get to these results, failure needs to be an option. This is a change in military culture, but it is achievable. In the appendix, we document one unit's efforts, on the USS *Preble*, to make this culture change. Notably, the commanding officer stressed the need for a culture where failure is acceptable: "You know your process is a success when a sailor is comfortable walking into your state room [office] with the stupidest idea you've ever heard."

[108] Maj. Timothy Trimailo, "Why Leaders Must Fail to Ultimately Succeed," *Military Review*, Nov.–Dec. 2017.

Strengthen Lessons Learned

In Edison's efforts to develop a new kind of battery, he tried thousands of experiments before finding success. But what if Edison had not kept track of those experiments and which approaches had not worked? He would have been much less likely to have found an effective solution. Similarly, studying past operations and identifying lessons regarding what worked, what did not, and why, can help the military to be a better learning organization. A number of the historical case studies include deliberate efforts to learn from current or past operations. However, the U.S. military has struggled with identifying and learning lessons.

Farrell, in his work on adaptation of UK forces in Afghanistan, noted that the UK military has a "weak" lessons learned institution.[109] A Joint Staff study in 2011 observed the same for the U.S. military, with several specific shortfalls. Lessons learned organizations were often not resourced sufficiently to collect and analyze pertinent information and identify lessons. In addition, the approach to identification of lessons was often to make observations that were not contextualized and thus less useful for learning. And finally, there was a weak tie between identified lessons and institutional change.[110]

There are exceptions, of course. In October 2011, Chairman of the Joint Chiefs General Dempsey asked the Joint Staff J7, LtGen George Flynn, to identify what lessons the U.S. could learn from a decade of operations since the attacks on the U.S. on September 11, 2001. The result was a report, "Decade of War, Enduring Lessons from the Past Decade of Operations," produced by the Joint Staff J7 Joint Center for Operational Analysis (JCOA) and featuring a collaborative approach involving the military services and combatant commands. The study reviewed "46 JCOA studies dating from the organization's inception in 2003 through early 2012, examining over 400 findings, observations, and best practices in order to identify enduring lessons that can inform future joint force development."

But such an effort is just the first part of institutionalizing lessons. It is a two-step process. First the lessons are identified and documented over time, creating an inventory of insights that can be referenced in the future.[111] And second, these lessons and insights need to be folded into

[109] Theo Farrell, Improving in War, 2010.

[110] Joint Center for Operational Analysis, Adaptive Learning for Afghanistan, U.S. Joint Forces Command, Feb. 2011.

[111] "Evidently President Abraham Lincoln was a believer in the value of lessons learned from war, remarking: "Human nature will not change. In any future great national trial, compared with the men of this, we shall have as weak and as strong, as silly and as wise, as bad and as good. Let us therefore study the incidents in this [war] as philosophy to learn wisdom from and none of them as wrongs to be avenged." Abraham Lincoln, Nov. 10, 1864, https://www.nps.gov/liho/learn/historyculture/1864election.htm.

decision-making processes. As the 2011 JCOA study indicated, that connection between lessons and institutional change appears to be weak.

One potential reason for this can be a belief that the past is different than the present and future, thus there is no value—or even perhaps a risk—of trying to understand past lessons. Murray has refuted this view, saying, "Historians have often suggested that military organizations study the last war and that is why they do badly in the next. In fact, few military organizations study the past with any degree of rigor, although the success of those that do so has demonstrated its vital importance."[112]

The example of Edison shows how innovation is empowered by learning. To better enable innovation, the U.S. military should improve its ability to learn key lessons and avoid the mistakes of the past, better resourcing its efforts to identify lessons and then drawing upon those lessons in decision-making. This does not simply happen; rather, it requires leaders to insist on it, asking, as CJCS Dempsey did with the Decade of War study: What can we learn from this? Then they must resource the efforts to find the answers and then push for such answers to be considered in future decisions.

Defeat the Myth of Technology Solutions

Compounding the difficulty of convincing military leaders to stray from the status quo and that the hard and costly work of innovation is necessary is the idea that *technology and firepower are sufficient to achieve lasting strategic results in war.* In the German jet case study, we see that this idea does not match reality. But despite evidence to the contrary, for a hundred years, the U.S. military has gone through cycles of believing that advanced targeting approaches alone could lead to decisive outcomes. The ability of this idea to be killed and yet to live again led then LTG McMaster to call this belief the "Vampire Fallacy."[113] Then Chief of Staff of the Army Mark Milley also described the belief that "wars can be won with advanced technologies" as a myth: a potent myth that can influence senior leaders, policy-makers, and political leaders to emphasize technology in budgets, force structure, and operational plans and concepts.[114]

Today, the promise of artificial intelligence, autonomous weapons, hypersonic weapons, and networks of fused surveillance and intelligence can seem to be the answer to competition. Indeed, they are a vital part of that answer. But the 2018 NDS recognizes the siren song of

[112] Williamson Murray, "Military Culture Does Matter," *FPRI*, Jan. 21, 1999, https://www.fpri.org/article/1999/01/military-culture-does-matter/.

[113] LTG H.R. McMaster, "Continuity and Change," 2015.

[114] Minutes, National Press Club Headliners Luncheon with U.S. Army Chief of Staff General Mark Milley, Jul. 27, 2017, https://www.press.org/sites/default/files/20170727_milley.pdf.

technological solutions that represents the Vampire Fallacy, and it calls for a more comprehensive solution: relying on lethality but also resiliency and innovation to present complex challenges for adversaries that they cannot prevail against. In the same way that the U.S. military pursues lethality through technological capabilities, innovation should also be front and center in its efforts to win in this competition. Consequently, the elements needed for innovation described in this report need to be prioritized and resourced by leaders as much as technology solutions.

Innovate at Any Level

It would be easy to recommend to "innovate at every level," or even that every soldier, sailor, marine, airman should be an innovator. But the military is the largest organization in the world, with considerable requirements that need to be sustained every day.[115] While innovation is important, even vital, to the continued military superiority the U.S. requires for national security, that innovation must be achieved while also sustaining its myriad requirements for operating.

So, instead, we recommend "innovate at any level." This is to reinforce the point that transformative, disruptive changes do not necessarily come from top leadership. History is replete with examples where individual units at various echelons had an idea, experimented with the idea, and it resulted in fundamental changes in warfighting. For example, 2nd Marine Division set out to explore the concept of maneuver warfare in 1980, experimenting and developing concept of operations and draft doctrine, and those ideas were adopted by the service as a whole.[116] Similarly, in the late 1960s and early 1970s, Pacific Fleet took the initiative to experiment with new concepts of anti-submarine warfare, marrying exercises and assessments to both find new vulnerabilities and identify new solutions to better face the Soviet submarine threat.[117] And, of course, the leadership of the USS *Preble* encouraged their crew to explore new ideas and solutions to a variety of operational problems, leading to a flurry of ideas and wide recognition within the Navy for producing new solutions.

Not everyone on the USS *Preble* contributed ideas for their innovation initiative. And not every servicemember has the capacity to consider innovative ideas. This is a process that requires

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[115] The second-largest organization in the world is China's People's Liberation Army, while the third is Wal-Mart. Sue Chang, "U.S. military is the largest employer in the world," *MarketWatch*, Jun. 17, 2015, https://www.marketwatch.com/story/us-military-is-the-largest-employer-in-the-world-2015-06-17.

[116] Terry Pierce, Warfighting and Disruptive Technologies, 2004.

[117] Adam Grissom, "The Future of Military Innovation Studies," 2006.

resources: those resources are not infinite, and the U.S. military needs to continue to meet its sustainment requirements. But any level can innovate, where there are resources to do so.

In the previous section we noted that while most steps of innovation can be either top-down or bottom-up, the last step—institutionalizing solutions—is inherently a top-down process requiring leadership focus. But the other steps of innovation—identifying problems, generating ideas, and refining solutions—can all be done at any echelon, as the USS *Preble* example shows. And such innovation efforts at lower levels can change the military forces as a whole in fundamental ways, as was seen in the Marine Corps shift to maneuver warfare due to innovation efforts by 2nd Marine Division.[118] While innovation efforts by a single unit or command have no guarantee of changing the larger force, history shows it can happen.

Summary

In a new era of great power competition combined with an environment where the tech sector is developing new technologies faster and with more resources than governments can, it is particularly important that the U.S. military be deliberate in taking steps to promote innovation. As the 2018 National Defense Strategy rightly acknowledges, innovation is a key part of successful competition. If that is so, then it is doubly important to understand what innovation is and what can be done to foster it.

Overall, we see it takes deliberate efforts to cultivate innovation. While innovation is a key goal of the NDS, we have seen that practical examples of innovation face significant challenges, needing to overcome considerable institutional resistance to be realized. This is consistent with Rosen's observation that military institutions are "especially resistant to change."[119] While DOD is pursuing ways to accelerate acquisition, this is not sufficient for making innovation successful; rather, it must also create an ecosystem where ideas can be cultivated, explored, and supported as appropriate. The recommendations above provide a way to do that. While some of these recommendations can only be achieved by senior leaders, others can be done at any level, and indeed they should be. But ultimately, successful innovation will require action, both to create an environment where innovation flourishes and to push past institutional resistance to enable more rapid progress. As the U.S. faces new contests to its national security by competitors, maintaining its military edge will require such action.

[118] Terry Pierce, Warfighting and Disruptive Technologies, 2004.

[119] Stephen P. Rosen, Winning the Next War, 1994.

Conclusions and Recommendations

Innovation is called out by the 2018 National Defense Strategy as one of three components needed to successfully compete in a new era of competition. But what is innovation? We examined DOD innovation initiatives, past CNA research, and academic literature regarding military innovation and developed a functional definition of innovation to help DOD pursue this NDS requirement. We see that current DOD initiatives are largely focused on improving rapid acquisition. While DOD's limited focus is valuable, our analysis shows that it does not match the more comprehensive scope that innovation represents.

We then set out to answer the question: What does successful innovation require? We examined some practical cases of historical innovation and used them to create a framework for an innovation process DOD can use for pursuing innovation. We see that innovation can face a number of challenges that can significantly delay success, requiring practical actions to promote the various steps involved in innovation. Based on that framework, we recommend some steps DOD can take to promote more effective innovation in pursuit of its 2018 NDS goals:

- Develop a process to define and prioritize operational problems to help focus innovation efforts
- Expand opportunities for idea generation, dedicating resources to foster idea-generation activities
- Resource learning and innovation by conducting experimentation, running wargames, and conducting robust assessments to refine ideas and develop solutions
- Create a learning loop by coupling experimentation, assessment, and wargame activities, synchronized by a learning campaign plan to provide feedback improved learning
- Protect and support innovators when their ideas and initiatives can be seen as threatening to the status quo
- Embrace failure as a cost of learning, providing a safe environment for innovation efforts
- Improve lessons learned processes to avoiding the mistakes of the past: better resource efforts to identify lessons and then draw upon those lessons in decision-making
- Defeat the myth of technology solutions to war: emphasize and resource innovation along with technology initiatives in order to present complex problems for competitors to address

- Seek innovation at any level: individual units or commands can explore new ideas and solutions to a variety of operational problems, creating bottom-up as well as top-down innovation.

This deliberate approach to cultivating innovation in practice will help DOD to make its innovation process timelier as well as maximize the benefits to mission effectiveness. In a time where technologies such as artificial intelligence, hypersonic weapons, and autonomous systems are seen as decisive capabilities, we note that in an era of competition, when time matters as much as effectiveness, these steps are just as vital to national security and should be pursued with the same vigor.

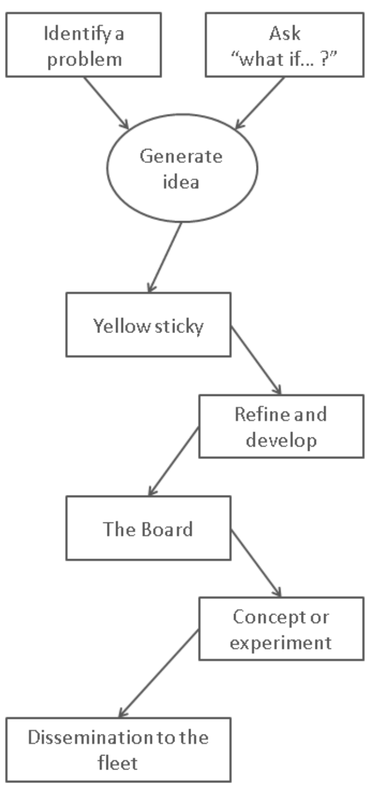
Appendix: Innovation at the Unit Level (USS *Preble*)

In this report we give the example of a Navy ship, USS *Preble*, and how they took a deliberate approach to innovation. In this appendix, we discuss specifics of this process, step by step. In addition, we discuss some overall themes that arose during interviews with the crew.

Starting Points

We discussed in depth with different groups how the divisions or individuals came up with the initial idea that led to an innovation. There seem to be two principal methods that sparked ideas—the first and easier method was to look for a problem, define it, and creatively consider solutions. The second was harder: research a system or a tactic and hypothesize how it might be improved.

Figure 5. Innovation development process aboard USS *Preble*



Look for problems

The first step in generating an idea was most often when someone in the crew identified a problem that existed. All members of the crew took part in this process; but junior sailors, officers, and Naval Academy midshipmen were particularly effective at noticing problems because they were not constrained by years of experience. Older, more experienced crew members often did not recognize problems because they were too familiar with the systems: "*Thirty years of training makes it hard to think outside the box—especially if you have been professionally successful in that box—so I have to rely on junior officers to notice stuff*."

An example of a problem the crew identified was water intrusion over the flight deck. Water intrusion is a dangerous condition where a wave can sweep a helicopter and its crewmen off the deck and into the ocean. Ship captains are warned against water intrusion. At the problem identification step, the sailors determined that there was no good method to quickly assess the danger of a situation based on interactions of the different risk factors—sea-state, ship speed, directions of wind, and turn.

Hypothesize

Another, more difficult method to generate ideas was to ask "what if" questions about systems or techniques. This method relied on subject-matter experts, often the second- and third-class petty officers, to explore and exercise their curiosity about their systems or the ship's mission. That curiosity generated hypotheses about how the systems or missions of the ship would function under different conditions. The method also used ad hoc playful experimentation that the crew was empowered to perform. For example, if the crew had ideas of how the thermal signature of the ship changed in different conditions, they could ask the helicopter crew to use their night-vision cameras at an arising opportunity. These quick tests provided the initial observations that the crew used to generate ideas and potentially innovative operating techniques or tactics.

One of the advantages that USS *Preble* enjoyed on its independent deployment was freedom to test out ideas. This flexibility is generally not available during workup or maintenance phases, nor when deployed as part of a carrier strike group. The crew and leadership advocated for a "go be playful" time in the deployment cycle, when crews can experiment with ideas and better learn the limits of their systems without the pressure of other tasking, inspections, or training.

Considerable knowledge and research were often required to begin understanding these what-if ideas—several were the result of bored sailors reading complex technical manuals and asking each other probing questions. As a result, this method was seen as the more difficult way to generate ideas, but it also provided some of the most creative and impactful innovations.

Generate the innovation

The most creative step in the process involved coming up with an initial solution or novel method based on the problem or idea identified. In some cases, sailors developed the innovation on their own, but it was more often a collaboration with their peers. At this step the innovation was discussed, developed, and written up in a standardized proposal format.

In the case of the water intrusion problem, the navigator hypothesized that the different risk factors could be included into a “whiz wheel” (a circular slide rule device) that could be kept on the ship’s bridge and quickly used to assess the risk, based on conditions and ship parameters, of a wave washing across the flight deck.

Many of the tactical innovations advanced by USS *Preble* were developed among the sailors who work in the combat information center (CIC). When the ship is in a high-risk environment, these sailors are focused on operating the tactical systems that defend or fight the ship; but sailors recounted that in low-risk environments it is not busy in CIC and there is a culture of discussing “cool ideas.” These discussions among operators provided the collaboration platform that led to innovative tactical solutions. Several sailors noted that CIC on USS *Preble* was chattier than their previous ships and, despite the acknowledged tactical creativity, had concerns that it appeared unprofessional.

The creativity and innovation development in CIC might be a result of leadership interest in tactics. But the CIC divisions pointed to three other factors that drove their creativity:

1. CIC is staffed with a diverse variety of operators who are subject-matter experts on different tactical systems. It is easy to find someone who either knows the answer or knows that there is no answer.
2. The space and work pattern of CIC is particularly conducive to brainstorming. CIC occupies a large open space in the heart of the ship, and the fluctuating workload—at the risk of boredom—allows time for discussion and collaboration.
3. Unusually for a Navy ship, the leadership consulted the operators about the watch bill (the individuals on each shift or “watch”), so operators could choose their collaborators and set up teams that worked well together.

Other departments such as engineering or supply tend to have a more encapsulated work environment with fewer people and less diversity of work functions. These departments certainly had innovation initiatives, but they did not reach the same levels of creativity and productivity as the CIC divisions.

Logging an innovation ("yellow sticky land")

When an individual or group developed an innovative method or solution, they initially socialized the idea with their immediate chain of command, often the chief petty officer or the division officer. Knowing that the ship leadership was interested in ideas, the innovator or innovative group was encouraged to tell the ship captain about their idea. At this point, the ship skipper, executive officer, and some department heads would discuss the merits and challenges of the idea with the innovator or innovative group.

At that point the skipper wrote the idea and the names of the originators on a yellow note that he stuck to the wall of his office with others. The individual or group was sent away to further develop the idea, possibly with significant encouragement from their leadership—or possibly with the awareness that there was some skepticism that they would need to overcome. While the ship leadership encouraged everyone to come up with ideas, there was some rigor at this step: some sailors were told that their ideas were not winners, although based on their comments, many found that discouragement motivational.

The yellow sticky note may seem trivial, but among the crew it had the effect of making the idea or innovation tangible. There was an awareness that the innovation was now real and had the attention of their captain, even if there was not necessarily pressure to further develop the idea. It provided leadership with a form of cheap and plentiful recognition; there is a danger that participants interpret this recognition as a demeaning "participation trophy," but the sailors did not see it that way.

Developing and refining concepts

At the next step the innovation was refined and developed from a one-page point paper to a more detailed solution, often in the form of a concept of operations, a detailed white paper, or an experimental design for the ship to test. In this stage, a prototype whiz wheel was built that could predict the danger of water intrusion.

This phase was almost always collaborative. If there was significant interest from the ship leadership, input would be pushed from both up and down the chain of command, and laterally with expertise from other fields. Chief petty officers provided insights on the higher-order impacts that the innovation might have across the workings of the ship. There was an interesting dynamic based on the source of the idea:

- If enlisted sailors originally generated the idea, then at this stage the project would incorporate officers to provide broader tactical insight to the concept and polish the writing.

- Concepts that originated with officers worked best if at this stage they incorporated the enlisted sailors who were the technical subject-matter experts on the systems involved.

In the words of one of the enlisted sailors on USS *Preble*: *"We had to work ideas up the chain, the ideas the officers had worked best if they worked them down the chain and involved us early on—we know what our systems can do and it's hard to innovate against the laws of physics."*

This phase of the process also involved significant research, usually requiring access to civilian or military sources on different computer networks. This was a challenge from a destroyer because the bandwidth support is much lower than provided to larger ships. However, the crew members that conducted the research, often officers, reported that rather than getting frustrated they appreciated the opportunity to intellectually explore the concepts. This was another point in the process where the time and effort to research the problems often had unexpected benefits: researching background for one innovation could lead to ideas for other tactical improvements or an awareness of problems that needed an innovative solution.

The Board

The individual or team responsible for an innovation would again meet with the captain and other stakeholders on the ship when their concept had significantly increased in sophistication and development. At this point, if it was judged to have tactical merit, the idea moved out of "yellow sticky land" and was written on a large board outside the skipper's office with the name of the individual spearheading the project. The idea originators also had the opportunity to name the innovation at this point, a method of creative branding that was also fun; a clever name was often a motivation for others to collaborate and help to develop the idea.

Available to the entire ship and posted in a prominent location, the board served several roles in the innovation process:

1. It was a direct communication to the crew about the different types of innovation project that were in progress and a point of contact if they wanted to engage the planning and refinement effort.
2. The Board was also a strategic communication that innovative solutions and ideas were supported by the ship leadership; this was intended to entice the creative and encourage new ideas.
3. It provided recognition and command encouragement to the specific projects and individuals.
4. It represented accountability both for the leader of the innovation project and for the captain of the ship: the Board was a to-do list, and the project leader and the ship

captain were responsible for getting the project refined, tested, and communicated to the Navy at large.

For many on the ship (and many that visited the ship during its deployment) the Board was the talisman of the *Preble*'s innovation initiative.

Experimentation

Not all innovative solutions or tactics could be tested or experimented with during the deployment, for example, some required resources unavailable to a single ship. However, when feasible, the crew experimented with the proposed innovation as a proof of concept.

Experimentation was another process in itself. The crew said they eventually developed a method for writing test plans and running the test, defining not just the steps during the experiment, but also working to specify the variables and how to collect the right data, scheduling time when the required systems were available, and creating a template to document the results.

Finally, during our discussions of experiments, the crew stressed safety. The environment that fostered innovation also empowered individuals to speak freely about safety concerns, and each experiment included an open discussion of contingencies that might take place during the testing. That is not to say that any individual on the ship could cancel an experiment by claiming it was unsafe or unwise to conduct; rather, the concerns were raised and considered or mitigated by the ship leadership.

Documentation

Writing was essential to the success of innovation projects. A written document, or at the very least a series of explanatory diagrams (in PowerPoint), was essential both because it provided the discipline to consummate the concept and because the document could be used to communicate the idea to an external audience off the ship.

In some cases, the responsibility for writing was given to an officer and the report went through repeated iterations with the ship skipper to refine the writing. In other cases, the responsibility remained with the sailor who originated the innovative idea, and the process was used as part of the sailor's personal development.

Dissemination

We heard that other ships have good ideas and develop innovative solutions and tactics, but those tactics never leave the ship or stay isolated in a specific community. How was USS *Preble* different?

When an idea was sufficiently developed to share with the larger Navy, the *Preble* skipper was responsible for finding it a pathway to a command or organization that could further develop it—either through a tactics experiment or development into tactical publications. Finding pathways was particularly challenging, especially with the diversity of innovations developed onboard.

Iteration of the process

Failures

Both crew and leadership on USS *Preble* viewed failure as an important performance metric for the innovation process: the more failures, the better the process was working. One reason for this was that even ideas that subsequently failed could spawn new ideas or increase the awareness of problems to other members of the crew who were then able to focus their own creative thoughts on the problem. So simply having a bunch of ideas in the system was productive.

But failures also indicated that the innovation process that they devised was effective at eliciting ideas and innovations from the ship's crew. The *Preble* leadership was concerned that a great idea might not enter the process because it would initially appear foolish, and that the crew member with the idea would resist suggesting it because others would think it silly. Therefore, if silly ideas were not being generated (and, being truly silly, failing during the process) then that indicated that not all the good ideas were bubbling up. In the words of the ship skipper, "*You know your process is a success when a sailor is comfortable walking into your state room [office] with the stupidest idea you've ever heard.*"

Feedback

At every stage, even—perhaps, especially—after dissemination from the ship, the sailors valued feedback. Often feedback from the original idea spawned new insights and questions that subsequently branched into new innovations; as a result, an eventual successful innovation might be very different from the original problem or idea that entered the system, and a single original problem could branch into many different eventual innovations.

Some feedback was formal: the Board provided a central source of information about how projects were developing. On a regular basis, the ship skipper would provide public address (1MC) updates to the crew about how different innovation efforts were progressing. Long after a sailor turned over a project to an officer for development and documentation, he or she could expect an email from the captain, forwarding comments from a senior Navy admiral about their innovation.

Process Summary

On their 2015 independent deployment, the USS *Preble* developed a process to cultivate and spread new ideas. This process was not in place at the start of the deployment, in fact by some estimates it was not running smoothly until about halfway through their cruise. Even when it was operating effectively, it is not clear that all sailors, or even leadership, grasped the role that each step played in the creative process—they simply knew that there was a next step and what that step involved. Some of the key attributes of the system included:

- Comfort in suggesting and discussing new ideas
- A pathway forward for the idea, including a test if possible
- Documenting the solutions
- Accepting failure as a metric of success.

Our diagram of the process is linear, but in fact there were many feedback loops from later steps to earlier steps, and this allowed ideas to branch and proliferate.

The crew of USS *Preble* developed a process that worked for their ship and their environment. It is possible that this is not the only effective process, and also that this process will not work as well in other units or environments. That said, the process aboard *Preble* mirrors closely the scientific method: use observations to build hypotheses; use experiments to test the hypotheses; and communicate the results so that others can replicate, benefit, and build from the new knowledge. The sailors on *Preble* recapitulated in their own form a method of learning first developed by Aristotle.

Finally, we asked if there were other pathways or processes for innovative ideas—perhaps an anonymous suggestion box, since these are common on ships. The response was astonishment: *“Why would I suggest my idea anonymously? I own it.”*

Figures

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