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Acquisition of Software-Defined Hardware-Based Adaptable Systems

Maura Rose McQuade—was a program manager and research associate in the Defense-Industrial Initiatives Group at CSIS from 2017 to 2019. [mrm310@georgetown.edu]

Andrew Hunter—is a senior fellow in the International Security Program and director of the Defense-Industrial Initiatives Group at CSIS. From 2011 to 2014, he served as a senior executive in the Department of Defense, serving first as chief of staff to Under Secretaries of Defense (AT&L) Ashton B. Carter and Frank Kendall, before directing the Joint Rapid Acquisition Cell. From 2005 to 2011, Hunter served as a professional staff member of the House Armed Services Committee. Hunter holds an MA degree in applied economics from the Johns Hopkins University and a BA in social studies from Harvard University. [ahunter@csis.org]

Schuyler Moore—was a research intern in the Defense Industrial Initiatives Group at CSIS in 2018. [schuyler.c.moore@gmail.com]

Abstract

The increasing importance of software has created an opportunity for the Department of Defense (DoD) to harness innovation through the acquisition and modification of systems that are (1) inherently multifunctional and (2) designed for continuous modification. Examples of these types of systems include radars, electronic warfare pods, and electro-optical sensor suites and are referred to here as adaptable systems. Identifying an acquisition approach to these types of adaptable systems that are software-defined and hardware-intensive is particularly challenging from an acquisition perspective. The optimal timeline for these systems does not fall into typical acquisition phases that discretely differentiate between phases such as research and development and production. The study team at CSIS has examined how the DoD presently acquires these systems and identified potential solutions to overcome the barriers found when adopting adaptable systems, some of which include more agile acquisition processes, open systems architecture, DevOps, flexible funding, development sprints, increased user feedback, and prototyping.

Introduction

Today's security environment requires the United States to prepare for defense against a wide range of adversaries. The 2018 National Defense Strategy (NDS) emphasizes that both the prosperity and security of our country is challenged by the reemergence of long-term strategic competition, a resilient but weakening post-WWII international order, and rogue regimes and non-state actors that destabilize regions critical to international security (DoD, 2018). Each of these adversaries is adopting and deploying technology in new and innovative ways, challenging the United States to be able to rapidly respond and adapt to a variety of threats. The Department of Defense (DoD) must reexamine almost every facet of its operations to assess what changes are required to enable effective responses to these new threats, and as part of this effort, the acquisition system is rightly considered a central element requiring reform.

Reform of the acquisition system is a continuous process undertaken by both the DoD and Congress in pursuit of objectives that are sometimes, but not always, aligned. In light of the 2018 NDS, the impetus for acquisition reform has shifted for both the DoD and Congress from a previous priority on cost control to a new emphasis on speed. This shift, while necessary in many respects, is not sufficient to address the requirements of the NDS. In addressing the need for greater speed, great attention has been given to streamlining, accelerating, and reforming how the acquisition process works. Comparatively less attention, however, has been given to the question of what the process is being optimized to deliver. This problem is critical because systems capable of responding to the wide range of changing threats identified in the NDS—adaptable systems—face a number of barriers in the current acquisition system. This paper identifies the need for and characteristics of adaptable systems, the barriers they face in the current acquisition system, the enablers that can allow for their successful development and deployment, and potential changes for the acquisition system that result from this analysis.

Section 1: The Need for Adaptable Systems

As the NDS notes, today's security environment is increasingly complex and defined by rapid technological advancement and changing character of war, where "the drive to develop new technologies is relentless, expanding to more actors with lower barriers to entry, and moving at accelerating speeds" (DoD, 2018). This rate of change challenges the United States to meet a variety of different threats, which are advancing and changing by the day. It states, "Success no longer goes to the country that develops a new technology first, but rather to the one that better integrates it and adapts its way of fighting" (DoD, 2018). The future threat environment suggests technological superiority or inferiority will not be static; instead, with the rise of peer competitors, defending national security necessitates the ability to quickly and flexibly leverage areas of strength and mitigate areas of weakness. History demonstrates that technological superiority may not always win wars; however, refusal to adapt to changing technology will almost always lose wars. Future success is therefore dependent on the nation's ability to adapt and rapidly adjust to uncertainties in threats, nimble adversaries, rapidly emerging (and obsolescence of) technologies, and new domains.

The rapid technological change occurring in commercial technology is a key driver in the strategic environment. Commercial technology development methods have advanced toward more agile processes that are better able to meet a rapidly evolving set of user-needs and customer demands. This shift is especially true in the area of software. Commercial industry is deploying continuous, iterative software-development that can harness technology advances, merge previously separate functions, continuously upgrade, utilize machine learning, and better leverage user feedback. The ability to use rapid developing commercial technology to drive adaptability in military operations is as equally available to potential U.S. adversaries as it is to United States and its as allies.

What Adaptable Systems Can Bring to Defense

The U.S DoD can capitalize on technology trends that have developed to meet rapidly evolving user-needs and customer demands through the design of adaptable systems. Adaptable systems are systems that have the inherent ability to deliver a wide variety of capabilities from a single basic design (multifunctionality) and can readily add capability over time (growth) at what former Defense Secretary Jim Mattis would term "the speed of relevance."

Adaptable systems are not new. Traditionally, features such as multifunctionality and growth potential were delivered in defense by very expensive, high-end systems that designed in excess space, weight, and power to support the addition of additional sensors and weapons. The classic example of this traditional approach to adaptable systems in defense are Navy ships, which grew ever larger in the 20th century to support a wide variety of missions and address a wide range of threats. In the 20th century, adaptability was an aspect of the most expensive systems in the arsenal and was a major cost driver.

The commercial technology sector has embraced a different approach to adaptable systems, using continuous, iterative software-development that can harness technology advances, merge previously separate functions, continuously upgrade features, utilize machine learning, and better leverage user feedback. The classic commercial sector example of an adaptable system is the smartphone, which has developed to absorb the functions of many previously separate devices, almost entirely through added software and networking. Increasingly, however, it is becoming clear that the characteristics of adaptable systems can also be achieved more cheaply and more successfully in the defense sector through writing new software rather than building and adding new hardware.

Today's systems don't require massive scale and expense to achieve adaptability. Increasingly, they achieve adaptability because the most important elements of functionality are defined in software and can be modified without substantial changes to the hardware. As a result, a piece of gear that can transmit and receive electrons may be a radio, radar, and an EW asset simultaneously, and it can be upgraded quickly as the technology evolves. These systems are hardware-based, but software-defined.

Additional Advantages of Adaptable Systems

While there is a compelling rationale for developing adaptable systems to compete with adversaries who are likely to be attempting to do the same, there are additional, inherent benefits to the use of adaptable systems. Adaptable systems, because they are designed to readily add additional capability, can speed the deployment of the key new technologies identified in the NDS, such as artificial intelligence and directed energy. Deploying these technologies in support of military missions requires integrating them in some form into new or existing military platforms, which adaptable systems can support. Adaptable systems can also reduce risk. The iterative, evolving nature of adaptable systems means that individual modifications are continuous and highly incremental. This creates the opportunity to reduce the scope of risk included in any individual upgrade as well as the ability to fail fast and move on when necessary.

While adaptable systems will present challenges to industry, particularly prime contractors who will have to manage in a far more dynamic environment, they also bring benefits to industry at multiple tiers of the supply chain. At the level of subsystem suppliers and component developers, adaptable systems create the opportunity for enhanced competition as the frequent modification and upgrade cycles generate new market opportunities on a regular basis. While electronics obsolescence is always a challenge, adaptable systems may be able to effectively avoid and mitigate technology obsolescence in subsystems and components more effectively, extending the useful service life of adaptable systems. Similarly, adaptable systems can ease the process of adapting U.S.-built systems for allied needs and/or incorporating interoperability with U.S. systems into allied equipment. In terms of life cycle costs, individual adaptable systems may not be cheaper to own than systems that hew closer to a static baseline, but it is possible that the efficiency of adaptable systems spending, in terms of capability delivered per dollar expended, could be high. Such increased efficiency in the DoD's acquisition spend could translate into savings elsewhere in the overall defense budget.

The Challenges of Adaptable Systems

Adaptable systems are inherently hybrid in nature. Because they are hardware-based, that is, they often have a metal superstructure such as on the array on a radar system, they look like hardware systems to the acquisition system and are generally handled as such. Because they are software-defined, however, it is the 1s and 0s of code that truly generate the bulk of the military capability that they deliver. However, acquisition processes developed solely for software may not address important aspects of what the and adaptable system is required to do. Adaptable systems still need to develop their sophisticated hardware elements as well as their software elements. An acquisition system that can successfully leverage the software components of hardware-based systems will harness continuous development, multi-functionality, and adaptability.

The multifunctionality of adaptable systems also can present challenges due to the interdependent nature of these functionalities. The Defense Science Board notes that "Unexpected complications can arise from unanticipated interdependencies within the software itself, often driven by the underlying architecture. A current DoD acquisition best practice is to reduce project risk by specifying the function of the software in detail at the beginning of a program" (Defense Science Board, 2017, p. 7). The more multifunctional and adaptable a system is, the more challenging it is to forecast the scope of its functionality and predict the independencies from the start.

Section 2: Adaptable Systems Usage in Defense

Before further discussing the barriers and enablers associated with developing and deploying adaptable systems for military missions, it is useful to examine some examples of the usage of adaptable systems in defense in greater detail.

Battlefield Airborne Communications Node

An example of adaptable systems in defense is the Air Force's Battlefield Airborne Communications Node (BACN), which originally leveraged a commercial aircraft base, relatively simple networking nodes, and lots of software to serve as a critical theater network hub connecting disparate parts of the joint force (Hlad, 2017). Since its initial development, the BACN capability has also been incorporate on unmanned platforms such as the Global Hawk. BACN is the opposite of the exquisite, expensive multi-functional military platforms of previous decades. It leverages the inherent ability of software-defined systems to deliver multifunctionality and growth by adding new code rather than new hardware incorporating additional communications links that allow it to connect more systems together as needed over time.

BACN provides a communications relay by translating data links and voice systems into a common output. This data sharing contributes to three objectives: it improves interoperability of platforms and systems using disparate communication forms, it allows ground troops to "see" the battlespace beyond the horizon, and it provides improved situational awareness and a common battle picture for all parties in a joint operation. BACN was initially developed as a Quick Reaction Capability (QRC) to address a Joint Urgent Operational Need (JUON) and was named a Program of Record in 2018. The system was originally meant to be a technology demonstration, but the Air Force was able to accelerate BACN development and fielded the system ultimately delivering four integrated BACN systems within 16 months (Northrop Grumman, n.d.).

Surface Electronic Warfare Improvement Program

The Surface Electronic Warfare Improvement Program (SEWIP) is an electronic warfare system comprised of radar warning receivers and active jamming systems and is integrated with a ship's self-defense system to trigger the deployment of decoys and flares in the event of an attack (Defense Industry Daily, 2019). SEWIP supports early detection, analysis, threat warning, and protection from anti-ship missiles.

The program uses an "evolutionary acquisition and incremental development" strategy to upgrade each system (U.S. Navy, 2017). SEWIP is modular with open architecture and is upgraded in blocks; SEWIP Block I was focused on obsolescence mitigation and special signal intercept, Block II provided electronic support capability improvement, Block III is in the process of adding electronic attack capabilities, and Block IV will integrate EO/IR capabilities onto the existing electronic warfare system (LaGrone, 2015). The most recent upgrade to Block III includes a shift to solid-state digital receivers and transmitters, allowing for more reliability and easier maintenance while making the system more adaptable (Freedberg, 2016). SEWIP exemplifies the multifunctionality available in an adaptable system by using primarily software changes to allow it to perform electronic warfare, electronic attack, and electronic intelligence functions.

AEGIS

The Aegis Weapon System is one of the more high-profile examples of a system shifting from a closed, hardware-dependent structure to an open, software-dependent one. Aegis was first fielded on a commissioned U.S. Navy ship in 1983, and the Navy's fleet of Ticonderoga-class cruisers and Arleigh Burke-class destroyers have all been outfitted with Aegis. The newest 11 cruisers and the whole fleet of destroyers are undergoing modernization that converts Aegis into an open architecture format, in addition to various HM&E upgrades (U.S. Navy, 2019). Additionally, the USS *Arleigh Burke* will be the first destroyer to be modernized to merge Aegis open architecture with Aegis BMD with the goal of ultimately giving the entire destroyer fleet BMD capabilities (Pearn, 2008).

The business model for Aegis' open architecture transition is composed of four parts. First, it requires concurrent development, integration, and testing to upgrade software capabilities. Second, it applies modern software engineering processes with agile development, rather than the traditional waterfall development. Third, it opens competition up to multiple commercial vendors for individual components of the software. Finally, it leverages points of overlap in capability development across weapons systems (DeLuca et al., 2013).

This process has taken place over multiple decades and ship upgrades. The first step was to implement COTS infrastructure and systems onto cruisers and destroyers to simplify the upgrade process and set a common standard. Next, some systems were broken down into component-based software decoupled from hardware to allow for a layered architecture and spiral development (software upgrades can now occur every two years while hardware refreshes occur every four). In recent years, more systems within Aegis have been transitioned to this open architecture framework based on their common set of components and application programming interfaces, referred to as "Baseline 9" (Durbin & Scharadin, 2011). As a result of the evolution of Aegis, it now functions as an adaptable system.

The current Aegis modernization program builds on previous upgrades and software developments. The next phases of development will include Aegis Modernization (AMOD) Advanced Capability Build 12 for both destroyers and cruisers, with each phase focused transitioning more components of Aegis to open architecture and allowing increased data sharing and communication between Aegis ships and the rest of the fleet.

Joint Tactical Radio System

An example of a program that experienced major challenges in part because it struggled to develop the characteristics of an adaptable system is the Joint Tactical Radio System (JTRS). The JTRS program (the JTRS program office was disbanded in 2012) sought to develop a set of software-defined radios intended to replace all existing radios in the U.S. military. JTRS sought to enable communication across a range of frequencies and waveforms, allowing increased interoperability both within the U.S. military and with U.S.

allies by converting analogue signals to digital. The JTRS program was built around the Software Communications Architecture (SCA) as an open architecture framework to enable rapid, flexible upgrades, and all JTRS components had to be SCA compliant (Military and Aerospace Electronics, 2004). The system comes in various formats: Network Enterprise Domain (NED); Ground Mobile Radios (GMR, now cancelled); Handheld, Manpack & Small Form Fit (HMS); Multifunctional Information Distribution System (MIDS); and Airborne & Maritime/Fixed Station (AMF). All systems can be upgraded with new software via a wireless information network, allowing for rapid insertion of new technologies across a broad range of systems.

However, the JTRS program has faced significant challenges along the way. Although GMR was certified for use in 2012, the Army ultimately cancelled that branch of the program due to cost overruns and technical challenges the program faced along the way. When the program first started, SDR technology was in its infancy, but JTRS GMR tried to accomplish too much and was constantly shifting hardware design and software requirements throughout the development phase. Furthermore, JTRS failed to adopt an agile approach that would have allowed for user feedback throughout the development process—instead, the program adopted a waterfall methodology that only allowed users to interact with the system after 13 years of development, by which point the problems in GMR were solidified and difficult to reverse (Gallagher, 2012). At the same time, developments in commercial SDR led industry to develop radios outside the JTRS program that provided capabilities the JTRS program had not been able to deliver. As a result, the JTRS GMR program was terminated in 2011.

Some programmatic descendants of the JTRS program are continuing to move forward. MIDS/JTRS has been successfully integrated onto platforms both in the United States and sold overseas, allowing for increased data interoperability between NATO countries. Both JTRS HMS and AMF has been fielded at low-rate initial production and its variants continue to be tested (Gallagher, 2018).

Section 3: Barriers to Adaptable Systems

While the case for the use of adaptable systems in defense is strong and there is a history of developing such systems in certain instances, there are reasons why such systems are not widespread. There are substantial barriers to the development and deployment of adaptable systems inherent in the defense acquisition system. It is crucial to understand what these barriers are and how they operate in order to develop an approach to overcoming them.

Design of the Traditional Acquisition System

For the DoD, adaptable systems are essential to fully leverage the capabilities of existing technologies to meet future warfighting needs. Software-defined, adaptable systems will play an increasingly critical role going forward. But these types of systems test the limits of the current acquisition system, which is accustomed to acquiring systems in a much more tightly defined and linear manner. As a result, the DoD has struggled to evolve at the same pace as commercial technology. The defense acquisition system was originally focused on Major Defense Acquisition Programs (MDAP) with long development cycles, enormous quantities, and tightly defined requirements because the system was designed to provide oversight to high-value hardware systems that were planned to remain in production for decades.

MDAPs almost always begin with highly detailed, highly defined requirements that specify in advance what threats a system is likely to confront and how it is expected to operate in military missions. While useful, this approach introduces the risk of over specifying systems toward problems which may morph rapidly over the long development and delivery time scales of defense acquisition.

The DoD 5000.02 acquisition milestone process is designed to progressively reduce technical risk by proceeding through discreet phases of development, test, and evaluation before entering full-rate production (DoD, 2015). If upgrade increments are planned, they are usually executed serially, not simultaneously. There are high transaction costs for change and high thresholds for justifying a new increment. Communication between the different elements of the acquisition system are organized around acquisition milestones and toward executing Milestone Decision Authority (MDA) directives. Such events are rare, and the stakes are high because the system is loath to deviate from or reverse these decisions.

However, adaptable systems (like other software-oriented development efforts) work best when developed in conjunction with frequent iterative feedback loops throughout the process. Under an adaptable systems approach, acquisition programs would be engaged simultaneously in development, production, and sustainment, which are not easily disentangled for review according to the traditional milestones. Instead, adaptable systems require continuous communication on requirements, budgets, and acquisition benchmarks.

Traditional acquisition metrics can be a major problem for adaptable systems. The Earned Value Management System (EVMS) is a common tool for measuring progress in acquisition programs. It is designed around breaking down a program's master schedule throughout its entire development into discrete work packages that register as earned value when they are completed at or below expected costs. EVMS as traditionally implemented, however, requires an almost entirely static program baseline, to function. When the content of work packages is subject to continuous change, the ability of EVMS to meaningfully track progress on the program decays rapidly. Given this contrast between the DoD 5000.02 acquisition system's need for discreet acquisition phases and benchmarks and adaptable systems' more fluid development processes, the traditional approach to acquisition hinders the critical elements for success for an adaptable system.

Budgeting

Current acquisition budgeting also presents roadblocks for adaptable system given the defense acquisition system orientation around MDAPs. Budgets for acquisition programs provide prescriptive funding at levels set years in advance that may be incompatible with the rapidly evolving needs of an adaptable system. Adaptable systems consider multiple new and expanded features for the upgrade cycle simultaneously. They will struggle in a budget process that requires both projections five years into the future for every technology insertion and detailed production and sustainment plans before moving forward on allocating development resources. There is precious little evidence of success in technology development that is budgeted outside of an MDAP and then transitioning into a major system, something that would have to happen frequently for adaptable systems to realize their true promise.

The DoD's budgeting process also includes separate "colors of money" for research and development, production, and operation and maintenance designed to support systems as they move through the acquisition lifecycle. Adaptable systems, however, do not move through the acquisition lifecycle in a linear way. They are almost constantly engaged in development, production, and sustainment simultaneously. While it is entirely possible for programs to budget multiple colors of money at the same time, it is almost inevitable with adaptable systems that these budget estimates will not keep pace with program developments creating the need for constant reprogramming of funds.

The multifunctionality of adaptable systems is also a major challenge for a budget process that organizes around distinct program offices and organizational lines of responsibility. A multifunctional adaptable system is difficult to procure in an acquisition and budget system accustomed to handling major functions such as communications, battlespace awareness, and electronic warfare as separate systems, procured by separate offices, using separate budgets.

Misaligned Business Incentives

Business incentives for industry can be misaligned for adaptable systems. Prime contractors derive their return on investment from anticipated work shares and the integration of known technologies. Configuration and design churn from adaptable systems could undermine prime contractor profitability and also create business uncertainty for first and second tier subcontractors whose business may be displaced. Additionally, defense prime contractors complain that adoption of iterative development methods is hampered by DoD contract requirements of documentation, milestone reviews, and incentives based on traditional waterfall-based models (Defense Science Board, 2018).

Rigid contract structures, such as fixed price development contracts, are a substantial barrier to the development of adaptable systems. Because these contract structures create powerful incentives for the government and the contractor to try to stick to the original contract terms to the letter, the ability to dynamically reshape program content and add capability is effectively precluded.

As RAND's Jonathan Wong (2016) has noted,

> If the Pentagon wants to reproduce the speedy results of rapid acquisition programs in peacetime, it must find more direct and efficient ways to determining effectiveness that involve the operational user earlier—and not penalize the contractor and the military for going back to the drawing board when something does not work.

Lack of In-House Technical Expertise

Both in-house technical expertise as well as external partners are essential for adaptable systems in delivering the technical level of software engineering needed as well as establishing appropriate requirements for software functionality. The DoD has struggled to acquire top software talent, which makes it difficult for all parties to speak in a common language and communicate software-based problems, as well as interact effectively with developers and testers to communicate needs, understand opportunities, and test performance. This has made it challenging to plan for and takes time to deploy upgrades to operating fleets and to train personnel on how to use them. Software-based systems not only require the necessary software talent but also the understanding of process and expectations from both commanders and policymakers. Finally, even as new systems are built to incorporate adaptability, the DoD is faced with the challenges of backward compatibility, cross-system interoperability, and increased variation in existing systems. This complicates both training and sustainment.

Section 4: Enablers

A variety of enablers exist to overcome or mitigate these barriers. Overall, these enablers encourage earlier and more rapid testing, flexibility in funding, requirements and new designs that are base platform/open architecture with ability to add on new, interoperable software-based payloads/capabilities that are each advancing with iterative and continuous development. They must also incorporate distributed, continual, and agile testing based on shared core architecture to make sure each update is integrated effectively, does not interfere with other component.

MOSA and Adaptable Architecture

MOSA enables adaptable systems by easing the process of integrating and replacing subsystems and components, as well as enabling flexibility, competition, and opportunities for distributed development. Architectures that are designed for adaptability from the ground-up make flexibility easier. This includes building systems that can easily incorporate new software-defined capabilities. MOSA should be a baseline expectation whenever a system will require adaptability.

Army Major General Bruce T. Crawford has explained that "the industrial base that supports the Department of Defense has been using software to modernize, instead of focusing on just hardware as the mechanism by which they've been able to increase capability." Software modernization in an open-architecture environment enabled this approach (Osborn, 2017).

Open standards allow for many different developers to contribute to a system over time, regardless of whether they were involved in the initial system development. This allows for more freedom of innovation and application due to dispersed development. According to Nick Guertin, senior software systems engineer at the Carnegie Mellon University Software Engineering Institute, MOSA "has helped the Defense Department improve its buying power. It opens up the market opportunities for the greatest possible number of buyers" (Brust, 2018).

In addition, MOSA can help outline possible modernization paths going forward. Maj Gen Zabel said,

> Open mission systems is a requirement for how every new system is built … and we are finding that it's been a great advantage in not only opening us up immediately to a larger part of the industrial base, but also giving us … a step by step modernization path. (Owens, 2017)

Incremental and Iterative Development

A variety of tools for incremental and iterative development can be adopted for software-based systems. These include the adoption of commercial software development techniques, such as agile development, DevOps, and development sprints, which enable adaptable systems by providing a foundation for iterative change and reducing, especially if combined with oversight regimes that eliminate the rigid predictability demands of the current acquisition system. Software-defined systems, if built for flexibility and adaptability, can prolong the effective lifecycle of their base hardware platforms while lowering cost of technology currency and potentially simplify hardware sustainment through reduced obsolescence.

According to Vice Admiral Mat Winter, Program Executive Officer for the F35,

> The current acquisition strategy has us doing a serial [and] sequential design, develop, integrate, test [and] deliver strategy. I'm not convinced that's the most efficient and effective way, most importantly, to deliver and continuously deliver capability to our war fighters … as we go beyond Block 3F.

Winter has worked to develop more of an adaptable systems approach to F-35 upgrades as part of the continuous development and delivery approach. “I am going to be asking the system to do things it’s never done before,” he said. “I’m asking the system to do true model-based systems engineering simultaneously with capabilities-based testing. The same time. With DT [developmental testing] and OT [operational testing happening at the] same time. Real time. Allowing us to be able to truly change the way we contract and cost estimate” (Insinna, 2017).

Increased User Feedback and Testing

Increased user feedback is necessary for software-based adaptable systems to both improve the functionality of the system, as well as incorporate the desired changes in real time. Increased feedback loops, a critical part of the agile process, will make sure the product that is delivered is the product the warfighter actually needs. This means increased use of things like prototyping, which provides real-time testing of systems in warlike environments, and expanding the use of virtual twin testing, where deployed systems can take real-time data and interact in real-time environments. For example, the Navy currently uses versions of virtual twin testing for its combat systems “so that new technologies can be tested by the crew and commanders before its uploaded into the main combat system, a hedge against reaping unintended consequences by uploading a feature or patch without knowing exactly how it will fit into the ship’s systems” (Larter, 2018). The army has implemented the use of beta-testing squadrons in order to field systems in real environments in Europe as well (Pawlyk, 2017). The air force is using a virtual twin prototyping approach for its program to reengine the B-52 bomber (Mayfield, 2019).

Increasing user feedback has a number of benefits. It recognizes that requirements and perceived optimal design may not actually operate as expected or anticipated. Additionally, this process encourages innovation among developers and the user community. “Maybe all the requirements aren’t met at the first go, but you have something that you can put in the hands of the operator and they can use it,” explained Air Force General Ellen Pawlikowski. “Once you put it in the hands of the operator, maybe some of the requirements you had in the beginning don’t make sense anymore, because [operators] see how they can actually use it and requirements change” (Owens, 2017). This means the traditional system to create test and evaluation as a separate phase from development is incompatible with iterative development. Even as systems are fielded, they will always be in a state of evaluation and upgrade. Air Force Maj Gen Zabel states, “In order to do that you need to integrated development and test to make sure that what you’re delivering to the field is actually worth delivering to the field” (Owens, 2017).

Finally, faster user feedback and real-time testing assists in developing software that can adapt to new environments and problems are emerging in close-to real time. Currently, the feedback time for warfighters to deliver input back from the field is too long to incorporate the changes into software in a timely manner. The DoD is therefore losing an opportunity to gain advantage.

Budgeting for Adaptable Systems and Flexible Funding

Budgeting for adaptable systems involves multiple aspects. In the first instance, it means budgeting within programs with the recognition that an adaptable system will not make a linear progression through development to production to sustainment. Rather, the program will be involved simultaneously in all three phases, with funding to support continuous software development remaining at a fairly constant level throughout most of the system’s lifecycle. Different services have adopted different budgeting strategies for software development, but the need to adopt budget mechanisms to support this is consistent across the DoD (McQuade, 2019, pp. 31–32).

The Defense Innovation Board has specifically recommended a new category of appropriation for software that would cover software activities currently funded variously through the operation and maintenance; procurement; and research, development, test, and evaluation appropriations (McQuade & Murray, 2019). Such a new appropriation would provide substantial flexibility in funding software development and fielding needs with a minimum of process friction compared to today's budgeting system. Existing tools could also be modified to reduce the friction currently caused by the need to reprogram funds from one appropriation to the another to facilitate agile software development. Helpful measures include clarifying and narrowing the definition of new starts, reducing the rigidity in colors of money so that reprogramming requests are less often necessary, broadening budget justification language to cover broader scopes for research and development, and providing more readily used mechanisms for adjusting color of money.

Budgeting for adaptable systems can also mean creating programmatic space outside of MDAPs for maturing subsystem technologies that may have application across multiple platforms. Congress provided a potential framework for this approach in the National Defense Authorization Act (NDAA) for Fiscal Year 2017 by creating funds in each service for subsystem and component development and prototyping (NDAA, 2016). This approach would allow the military services to budget significant funding for research and development for technologies not directly associated with a program of record (and therefore likely not tied to a program of record requirement). Currently, the Small Business Innovative Research program is one of the only significant sources of R&D funding outside of programs of record, but the SBIR program is not accessible to firms that are not small businesses. Increased use of portfolio-based acquisition management may also be an enabler for more technology development outside of MDAPs (ACT-IAC, 2019). The Section 809 panel records managing acquisition more on a broad portfolio basis rather than focusing on individual programs of record. Such an approach could allow for technology developed in a portfolio to be adopted widely among adaptable systems within the portfolio.

Contracting Mechanisms

Contracting mechanisms that best support adaptable systems are likely to be those that foster collaboration between the government and the prime contractor. The more collaboration there is in this relationship, the less effort that is required to establish tight specifications for every aspect of work. This suggests that it would be challenging, if not impossible, to carry out an adaptable systems program in a fixed price for development contracting model. Other Transaction Authority agreements (OTAs) and flexible contracting mechanisms, such as multiple award IDIQs, can allow for more flexibility in contracting for adaptable systems that can readily add and subtract work scope as needed. In cases where the collaboration may require coordination across large elements of an industrial sector the use of consortia and alternative competitive constructs may facilitate the coordination and continuous evolution of requirements throughout the acquisition process.

The Section 809 Panel recommendations for acquisition of technology that is readily available, and readily available with modification, can facilitate contracting for adaptable systems (ACT-IAC, 2019). Similarly, the Defense Innovation Board has proposed a streamlined authority creating software acquisition pathways that can provide a useful mechanism for adaptable systems, particularly for systems that were not original set up to be adaptable systems that are transitioning toward an adaptable systems structure (McQuade & Murray, 2019).

Dynamic Marketplace

A dynamic marketplace approach to working with industry, especially in acquiring technology with strong commercial elements, is recommended by the congressionally mandated panel on acquisition streamlining, also known as the Section 809 Panel (ACT-IAC, 2019). The dynamic marketplace approach involves fostering competition by obtaining proposals from industry prior to establishing discrete performance requirements. The goal of this approach is to leverage commercial innovation and non-traditional partners, placing military mission at the center of government/industry dialogue. Industry consortia can be a good enabler for many of these discussions. The dynamic market place approach can support adaptable systems by encouraging commercial practitioners of agile software development approaches to participate in defense acquisition and by reducing the impetus to define highly detailed performance requirements at the front end of acquisition programs.

Functionally-Aligned Workforce and Increased Training in SW Expertise

A functionally-aligned workforce and increased training in software expertise will also enable leadership and understanding of the opportunities posed by adaptable systems. With leadership buy-in, the DoD can specify technical career tracks, adjust for competitive talent acquisition, cross-service collaboration, develop a broader knowledge across the Department of Technology and offer competitive compensation for potential applicants.

Air Force Chief Technology Officer Frank Konieczny has discussed how the human element is a major factor in the success of agile software development in the Air Force. Turnover in the work force and challenges in tracking programming skills as part of a career field when making assignments make it difficult to have personnel continuity and the right mix of skills in pursuing agile software development (Williams, 2018).

The DoD must enhance its talent by both leveraging current expertise as well as attracting and retaining new talent. Specifying technical career tracks and establishing competitive compensation will significantly help. According to the NDS, the DoD plans to “emphasize new skills and complement our current workforce with information experts, data scientists, computer programmers, and basic science researchers and engineers—to use information, not simply manage it” (DoD, 2018).

Issues with the workforce are not limited to dealing with the development and management of software expertise among those writing and working directly with software. As emphasized in the workforce recommendations of the Defense Science Board study on software acquisition, the DoD also needs to increase software awareness and understanding among program managers and program executive officers as well as in managers in industry (Defense Science Board, 2018). Establishing a culture supportive of adaptable systems will take time and will entail taking a different view of risk. According to DIUx Managing Partner Raj Shah, “For us internally, if a team or project team really stretches to try a technology or approach that’s really novel but there’s technical risk involved … technology risk is acceptable and for a certain level we encourage it” (Carberry, 2017).

Section 5: Overall Strategy

While the enablers required for adaptable systems already exist and do not necessarily need new authorities to be implemented, actually combining these tools in an effective and coordinated way remains difficult. It is ultimately essential to understand how these enablers work together and begin a larger environmental transition toward their use. While elements across the DoD are taking steps to implement a variety of the enablers listed above, the use of many of them is still comparatively rare and it is even rarer to see several of them used together.

In order to achieve success in the acquisition of adaptable systems, the DoD may consider the creation of a clearly defined adaptable systems lane. The DoD currently describes its Adaptive Acquisition Framework as one that includes a variety of approaches including the Section 804 Middle Tier of Acquisition approach, rapid acquisition, and traditional acquisition. This framework could be expanded to include an adaptable systems lane as well. Systems in the adaptable systems lane would default to the use of the enablers described above rather than using them by exception. More traditional approaches could still be used, but they would be the exceptions in the adaptable systems lane. If an adaptable systems lane were created, however, it would be important to ensure that it not monopolize the use of these enablers. The goal of this effort is to enhance the ability of program managers and other acquisition leaders to appropriately use the right tools to acquire adaptable systems, not to impose limitations or straightjackets on them.

Conclusion

Deploying systems that are adaptable and agile is not just a technology strategy, but a security imperative. Success will ultimately depend on the DoD's ability to adjust rapidly to uncertainty in threats—nimble adversaries, new domains, and unanticipated applications of technology utilizations. Our current acquisition debate is currently failing to directly address the changing nature of what we need to be buying, and as a result, we may be heading towards another round of acquisition reform recriminations in a few years. A successful approach to adaptable systems requires using the enablers identified in this report to overcome the barriers to adaptable systems.

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