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Modernizing the Nuclear Enterprise in the Era of Rapid Prototyping

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The U.S. nuclear enterprise is going through a cycle of modernization that touches practically every system in the arsenal. This modernization push requires the nuclear enterprise to engage deeply with the defense acquisition system—the collection of organizations within the Department of Defense (DOD) dedicated to fielding new systems and the policy framework they operate under—in a way it has not since its last major modernization cycle in the 1980s. This engagement will be central to the future of the nuclear enterprise and will challenge the enterprise to exercise exceptional discipline in articulating and managing its requirements to revitalize these systems successfully. Likewise, the defense acquisition system must deliver on multiple demanding requirements and produce sophisticated, modernized

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Banner: *An artist rendering of the future U.S. Navy Columbia-class ballistic missile submarine*.

Source: U.S. Navy

nuclear capabilities affordably, reliably, and on time. Moreover, this multi-decade nuclear modernization cycle does not occur in a defense acquisition vacuum. Rather, the defense acquisition system is undergoing a transformation that will play out at the same time, each posing risks and raising complexity for the other.

The acquisition system regularly undergoes cycles of reform that reflect shifting strategic priorities across DOD. The current reform cycle, which originated with new authorities provided by Congress in the National Defense Authorization Act (NDAA) for Fiscal Year (FY) 2016 and has been pursued aggressively by the current administration, is focused on acquisition speed. It utilizes decentralization, delegated decisionmaking, rapid prototyping, and more tailored contracting tools as primary development approaches. DOD has combined these recently expanded acquisition approaches with traditional acquisition approaches in a system it calls the Adaptive Acquisition Framework. The Adaptive Acquisition Framework will affect different parts of nuclear modernization differently.

The nuclear enterprise initiated its most recent modernization cycle slightly before this shift in DOD's acquisition approach took hold. Based on the content of the programs and the time frame for when they were initiated in the acquisition system, the B-21 bomber and the Columbia-class submarine are being acquired according to the most traditional part of the Adaptive Acquisition Framework—the DOD Instruction 5000 process for major defense acquisition programs. However, the newer approaches in the Adaptive Acquisition Framework, those focused on rapid prototyping and fielding, will still have significant impacts for the other components of the nuclear enterprise, including the Ground Based Strategic Deterrent (GBSD), which replaces the ground leg of the nuclear triad, and the Long Range Standoff Weapon (LRSO), which replaces the ACLM nuclear cruise missile assigned to the bomber fleet. The biggest impact, however, is on the modernization of nuclear command, control, and communications (NC3), where the rapid prototyping approach most strongly correlates with the content of the nuclear modernization program. Adapting to this approach will present challenges for the nuclear enterprise but also opportunities to benefit NC3 capabilities if handled well.

The Evolution of the Acquisition System

The acquisition system's current focus on speed and agility has its origin in some of the successes of rapid acquisition during the wars in Iraq and Afghanistan. The acquisition of IED-protected vehicles such as MRAPS, new UAVs and advanced ISR sensors, and biometric and networking capabilities for the wars demonstrated that DOD was capable of fielding significant new capabilities in a time frame of two years or less. These successes were achieved through rigorous discipline in setting requirements and leveraging commercial technology and government off-the-shelf technology with relatively modest modifications. Rapid acquisition programs also had access to robust and flexible funding from the Overseas Contingency Operations (OCO) account and strong support from senior leadership to do what it took to meet urgent operational needs. Congress took note of what had been done in rapid acquisition and asked how these techniques might be extended to a broader range of acquisition programs.

During the same period, programs proceeding in the traditional acquisition system were dealing with the substantial constraints of the Budget Control Act of 2011 (BCA). The BCA led to a roughly 25 percent reduction in DOD's budget that was magnified into a significantly larger reduction in funding for modernization programs when sequestration was implemented. A relatively small number of must-have major defense acquisition programs navigated through this treacherous budget terrain into full-bore system design and development. Fortunately for the nuclear enterprise, two winners in this process were the B-21 bomber and the Columbia-class submarine, programs that are set to modernize two legs of the nuclear triad. Both programs have schedules typical of traditional acquisition programs, timed to allow them to replace existing systems in the nuclear force that will be retired around the end of the current decade.

Because these systems are designed to operate in some of the most challenging environments and are tasked to perform complex missions flawlessly, they are likely to benefit from the rigorous engineering and manufacturing development required in the traditional acquisition system. Legendary acquisition figures such as Admiral Hyman Rickover and Dr. Paul Kaminski developed the traditional acquisition system to govern the development of nuclear submarines and strategic bombers. They put a huge emphasis on detailed systems engineering that manages the interaction of multiple subsystems with tightly coupled performance. In tightly coupled designs, the performance of each subsystem continually and significantly impacts the performance of the system as a whole. Nuclear submarines pack an enormous volume of advanced technology, including a nuclear power plant and multiple full-scale intercontinental ballistic missiles, into the relatively small size of a submarine hull and are also required to operate below the surface for long periods in near total quiet. Likewise, a low-observable strategic nuclear bomber such as the B-21 has to integrate all of the elements of a modern warplane, including highly efficient engines and large fuel tanks, advanced targeting radars, secure global communications linkages, sophisticated defensive systems, and large nuclear bombs, into an aerodynamically-efficient airframe with a miniscule radar signature.

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The systems engineering processes required to accomplish these feats are robust, and the traditional defense acquisition system is intended to enforce their implementation and verify it with rigorous testing. Both the Columbia-class submarine and the B-21 are currently in the most challenging stage of the defense acquisition system, transitioning from development to production, where nagging development issues must be resolved and costly initial production issues surfaced for the first time. The next few years are likely to be challenging ones for both systems, but the care with which both programs were planned in their early years should see them through these challenges to successful production and fielding.

Congress, however, grew impatient with the limited number and pace of traditional acquisition programs initiated in the years affected by the BCA and desired to speed up the delivery of new systems and drive more commercial technology into defense acquisition. It included provisions in the FY 2016 and FY 2017 NDAAs designed to speed up the acquisition process. The most notable of these for the nuclear enterprise were Section 804 and Section 815 of the FY 2016 NDAA. Section 804 established a process called the middle tier of acquisition, authorizing DOD to acquire new systems through a rapid prototyping and rapid fielding process to be completed in five years or less. DOD's enthusiastic adoption of the middle tier of acquisition in 2017 meant that most new major acquisition programs moving forward in recent years have utilized a rapid prototyping approach. The acquisition strategies for these programs are often based on a round of prototype development followed by the intention to rapidly field either that prototype or an iteration of that prototype. Notably, they are not required to engage in the detailed engineering processes required in the traditional defense acquisition system before proceeding to production and fielding.

Section 815 expanded the authority to use Other Transaction Authority Agreements (OTAs) to include their use in the production of systems as well as services such as commercial information technology and software solutions. OTAs are not required to include any of the contract clauses typically required in the Federal Acquisition Regulation (FAR), which makes them a particularly useful contracting vehicle for non-traditional companies that are not equipped to meet all the detailed contracting requirements typical in defense contracts. In addition, OTAs have been used with traditional defense contractors as a tool to leverage industry investment through cost-sharing and to encourage the use of commercially developed technology by utilizing alternative approaches to the industry's intellectual property. By leveraging these authorities, DOD has sought to use a rapid prototyping phase as either a complete or partial alternative to traditional system design and development, enlist independent industry investment in the early stages of system design, and entice non-traditional contractors to bring new capabilities to defense systems, particularly those that are software intensive.

In addition to these changes in acquisition authorities, Congress also made structural changes in the acquisition system. Section 825 of the FY 2016 NDAA mandated the delegation of milestone decision authority for most acquisition programs from the Office of the Secretary of Defense to the civilian acquisition executives in the military services. The milestone decision authority is the DOD official designated to determine whether an acquisition program has met the requirements to complete a stage in the acquisition process and proceed to the next stage. The transfer of this authority to the services made the Office of the Secretary of Defense an observer of the services' acquisition programs rather than a core participant in decisionmaking. Section 901 of the FY 2017 NDAA further decentralized acquisition authority by splitting up the office of Acquisition, Technology, and Logistics in the Office of the Secretary of Defense, splitting off responsibility for early-stage research and development to the new undersecretary for Research and Engineering. However, nuclear modernization was one area where Congress allowed a continuing coordinating role for the undersecretary of defense for Acquisition and Sustainment, who also chairs the Nuclear Weapons Council, so most of the decentralization changes undertaken in recent years may not immediately affect the nuclear enterprise that much.

Implications of Acquisition Reform for More Recent Nuclear Modernization Programs

Two major nuclear modernization programs, GBSD and LRSO, progressed through the defense acquisition system as the acquisition reforms described above were being implemented. GBSD is slated to receive approval for milestone B in late 2020 and is currently progressing in the traditional acquisition framework. GBSD is certainly a complex and tightly coupled system since it includes not only development of an intercontinental ballistic missile but also modernization of much of the missile launch infrastructure. However, Air Force Acquisition Executive Dr. William Roper has highlighted GBSD as a case study for a new Air Force approach to digital engineering in its acquisition programs. He argues that this approach, which utilizes highly detailed digital models to develop, test, and maintain in a virtual environment, will allow the Air Force to expedite many of the engineering and developmental test processes required in the traditional defense acquisition approach. For this reason, GBSD may show whether the acquisition system can be operated in a new way that delivers similar engineering outcomes to those required in the traditional defense acquisition system. The LRSO program is also currently planning to proceed through the traditional acquisition framework, with a milestone B decision pending in 2022. The Air Force has not particularly advertised plans to test out new acquisition techniques with LRSO so far, but since the milestone review process is only now beginning, it is too early to tell if LRSO might follow something like the hybrid path that GBSD is taking.

The clear outlier in nuclear modernization is the constellation of efforts to modernize nuclear command and control. Modernization of the NC3 system presents the acquisition system with a series of unique challenges but also with the opportunity to fully leverage newly developed acquisition authorities.

NC3 Modernization

The NC3 system encompasses a complex mix of subsystems, including satellites, radars, and ground stations; data terminals in a wide mix of aircraft, landlines, and relay stations; and command and control nodes on the ground and in the air, as described in a report by the Mitchell Institute and MITRE. These systems must interact securely and seamlessly with each other while spanning the globe to provide a clear picture of red and blue nuclear forces. As a system of systems, the NC3 system is required to perform five main, interrelated warfighting functions: (1) force management, (2) planning, (3) situation monitoring, (4) decisionmaking, and (5) force direction.

While the term "system of systems" has been common in defense acquisition for some time, there are precious few examples of acquisition success in developing system-of-systems architectures. Notable efforts to design and develop systems of systems, such as the Joint Tactical Radio System (JTRS) and the Future Combat System, have collapsed under the weight of their own complexity. A significant challenge in these efforts has included keeping up with the pace of technology development, especially in networking and communications, which has sometimes made systems such as JTRS effectively obsolete before they ever reach deployment.

The NC3 system has experienced its own challenges along these lines, as demonstrated by the Family of Advanced Beyond Line-of-Sight Terminals (FAB-T) program, which experienced substantial cost growth, schedule delays, and technological obsolescence issues. But FAB-T, which finally appears to be on track after a decade in development, is far from the most challenging element in NC3 modernization. In addition to the many complex individual elements in the NC3 system, the interconnections between these elements adds another dimension of complexity. In fact, one issue in the FAB-T program was the challenge of modeling all of the diverse and aging legacy elements of the NC3 architecture during the development phase, meaning that some issues were only discovered when the terminal entered operational testing with actual legacy systems. In the face of this complexity, traditional acquisition approaches which seek to predict and mitigate every risk on the front end of an acquisition program may be ill suited to NC3 modernization.

U.S. Navy Vice Adm. David Kriete, deputy commander of U.S. Strategic Command, announces the initial operational capacity of the Nuclear Command, Control, and Communications Enterprise Center (NEC), responsible for managing the NC3 modernization process.
Source: Staff Sgt. Ian Hoachlander

Applying New Tools to NC3 Modernization

The tools of rapid prototyping may present a better path toward developing the complex network of subsystems that constitutes the NC3 system. For many elements of the NC3 architecture, rapidly prototyping one or more potential candidates for replacing those elements offers a way to sustain and modernize critical subsystems, introduce new technology, and guard against technological obsolescence simultaneously. The nature of the nuclear force means that none of the various subsystems in the NC3 system need to be procured in large numbers, so a successful prototype can be fielded relatively rapidly once it demonstrates it can meet the rigorous requirements associated with nuclear command and control. A key to success with this approach will be the ability to realistically test prototypes with deployed legacy systems and the other nuclear systems currently under development.

Another key facet of NC3 modernization is the software-intensive nature of most of its subsystems. Given the nature of the sensors, command and control, and communications nodes involved, software drives the functionality of every element of the system. This dynamic is even more true for the fully digital systems that are likely to replace the legacy systems in the architecture. The pace of development in these software-intensive areas of technology is even higher than in other modernization programs. As a result, the NC3 modernization effort will need to employ flexible contracting approaches that allow it to keep pace with technology development. A key element of this approach is likely to be accessing a wide variety of software developers outside the traditional defense industrial base, as the Air Force has demonstrated with its Kessel Run, AFWERX, and Kobayashi Maru initiatives. This is where the expansion of OTAs could help NC3 modernization, especially in enabling the adaptation of software and networking capabilities with commercial origins through non-traditional providers.

The structural changes in the organization of the acquisition system have less clear implications for NC3, however. On the one hand, the undersecretary for Acquisition and Sustainment retains significant authority relating to nuclear modernization programs. On the other hand, the Air Force is the main service responsible for the vast majority of NC3 modernization efforts, which is likely to significantly empower service-level decisionmakers in those activities.

The Importance of Responsiveness and Requirements Discipline

An essential ingredient in rapid prototyping programs and software-intensive systems is the ability to be responsive, and at the same time disciplined, in the review of rapidly shifting user requirements. One of the key lessons learned from rapid acquisition, which inspired many of the recent congressional acquisition reforms, was to use robust user feedback to ensure the necessary responsiveness and requirements discipline. The fact that Strategic Command, the primary user along with the National Command Authority, of the NC3 system has been formally designated as lead for setting requirements for its modernization is consistent with these lessons learned. Since the Air Force will serve as the acquiring agency for most major elements of the NC3 system, there is a strong opportunity to apply the proper mix of responsiveness and discipline consistently. The Air Force also owns the largest share of major nuclear platform modernization programs, further emphasizing the importance of Air Force acquisition in ensuring that NC3 modernization stays synced up with the major platform modernization programs, including the B-21, GBSD, and LRSO.

The Need to Balance Opportunities and Risks

The current cycles of acquisition reform will have significant implications for nuclear modernization. The biggest impact is likely to be on modernization of the NC3 system. The current acquisition focus on rapid prototyping and flexible acquisition tools such as OTAs holds promise for addressing the inherit challenges and complexities of NC3 modernization. However, there are also risks in using these speed-oriented approaches to modernization that are important to note. Nuclear systems must be fault intolerant. Any anomalies in the NC3 system that could potentially result in a failure to detect and respond to an enemy nuclear attack, or, conversely, that could result in an unauthorized launch of a U.S. nuclear weapon, are simply unacceptable. This indicates the need for robust and continuous testing and evaluation of the NC3 architecture throughout its modernization cycle. It also emphasizes the need for a technically deep organization responsible for assessing the overall health of the system—such as a federally funded research and development center (FFRDC) to continuously assess the suitability and effectiveness of the NC3 system and identify and mitigate any emergent anomalies.

As already discussed, the NC3 system will assume an increasingly software-intensive and digital nature as its various elements undergo modernization. As a result, the NC3 system will present an increasing surface area for a wide variety of cyberattacks. It is highly likely that peer competitors such as Russia and China will seek to exploit these vulnerabilities, just as they have sought to undermine other U.S. capabilities that threaten their territory and interests. Pursuing NC3 modernization through a variety of prototypes and work with non-traditional contractors likewise increases the potential for risks arising in the industrial base. The acquisition system is initiating an approach for enforcing the implementation of cybersecurity standards in the defense industrial base known as the Cybersecurity Maturity Model Certification (CMMC) that is expected to go into effect in 2021. However, there are significant questions about the readiness of the industrial base to implement CMMC and about the effectiveness of the CMMC approach. If CMMC does not present an effective solution to cyber vulnerabilities in the industrial base, the NC3 System may have to develop its own certification approach to mitigate cyber threats.

Is It Okay to Stop Worrying and Love Acquisition Reform?

While NASA may have coined the phrase "failure is not an option," it is the nuclear enterprise that has worked incredibly hard to live by this creed. The traditional defense acquisition system, with its intense engineering rigor, may seem familiar and reassuring for the nuclear enterprise, especially since the defense acquisition system was created in many ways to meet the nuclear enterprise's needs. Most of the nuclear modernization efforts underway reflect this long-standing relationship, adhering to both the structure and intent of the traditional acquisition framework. However, in addition to the benefits of rigor and predictability, the traditional acquisition system also brings its own risks. The biggest challenge for traditional acquisition programs is making the transition from development to production and initial fielding. At this point, many program complexities which have been conveniently glossed over in the early stages become painfully apparent. Frequently, the true cost to complete these systems also begins to clarify, and to escalate. It is quite likely that we will see challenges along these lines associated with the B-21 and the Columbia-class submarine in the next several years. This may create pressure to terminate these programs, although that is not a realistic option for the Columbia-class submarines, or to bust these programs out of the traditional acquisition process to accelerate their delivery. By and large, however, the correct answer is usually to stick with the program, working through the pain and agony of transitioning to production, to reach the relatively calmer seas that usually lie on the other side of milestone C.

The NC3 modernization effort, however, faces an additional risk in the traditional acquisition framework which must be considered. There is a significant risk of the NC3 system being caught in a continuous state of technological obsolescence in the performance of its core functions unless it is managed in a way that allows for more rapid development and fielding of modernized capability that can integrate relatively seamlessly with legacy systems. Here, the new tools and approaches offered by recent acquisition reforms, if coupled with disciplined management of requirements, may offer the nuclear enterprise its most realistic opportunity for effective modernization.

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