SYM-AM-22-032

Excerpt from the Proceedings
of the
Nineteenth Annual Acquisition Research Symposium

Acquisition Research:
Creating Synergy for Informed Change

May 11–12, 2022

Published: May 2, 2022

Approved for public release; distribution is unlimited.

Prepared for the Naval Postgraduate School, Monterey, CA 93943.

The research presented in this report was supported by the Acquisition Research Program at the Naval Postgraduate School.

Harnessing the Power of Digital Platforms to Accelerate Adoption Rates of Emerging Technologies and Innovations

Carly Jackson—serves the Naval Information Warfare Systems Command (NAVWAR) Enterprise in several roles. She is the Chief Technology Officer (CTO), National Competency Lead for Science and Technology, and Head of the Cyber and Science and Technology Department at the Naval Information Warfare Center Pacific in San Diego, CA. In August 2016, Jackson became the first Senior Scientific Technical Manager responsible for rapid prototyping of information warfare capabilities across the Naval Research and Development Establishment. Jackson was appointed to the Senior Executive Service in July 2019. She holds a Master of Science degree in mechanical engineering from the University of California, Los Angeles, and a Master of Arts degree in business administration from Pepperdine University's Graziadio School. Her awards include the Navy Meritorious Civilian Service Award in 2017 and numerous team awards. She is DAWIA SPRDE-SE Level III and Program Management Level II certified. [carly.a.jackson.civ@us.navy.mil]

Tricia Nguyen—commissioned in June 2013 via the NROTC program at Oregon State University, where she earned a BS in earth science. Afloat, Nguyen completed her Division Officer tours aboard USS Mobile Bay (CG 53) and USS Bulkeley (DDG 84) as the Main Propulsion, Joint Electronics Repair and Communications Officer, and Damage Control Assistant. She deployed to 7th Fleet with the John C. Stennis CSG and conducted various operations in the North Atlantic. After completing the combat systems, applied physics MS curriculum at Naval Postgraduate School, she reported to the Naval Information Warfare Center Pacific in 2019 as an Engineering Duty Officer and has been involved in cyber S&T efforts. She is a JPME Phase I graduate. Her awards include the Navy and Marine Corps Achievement Medal (two awards), National Defense Service Medal, and unit awards. [tricia.nguyen@navy.mil]

Susan Lai— currently serves as the Branch Head for the Naval Networks Modeling, Simulation, and Analysis branch for Naval Information Warfare Center Pacific in San Diego, CA. She has been in this position for over 5 years and is responsible for a team of 18 scientists and engineers. The modeling and simulation branch has developed its own government developed network simulator called Sigma. It was developed leveraging open source software and has numerous Navy specific models that can be shared with government partners. The branch also encompasses RF modeling; mission modeling; cyber modeling; Position, Navigation, Timing (PNT) modeling; and Model Based Systems Engineering (MBSE). Lai's government career began in 2006 at NIWC Pacific as a New Professional. She went on to lead modeling and simulation studies for NAVWAR 5.0, PMW 790, National Geospatial Intelligence Agency, OPNAV N81, and DARPA. [susan.a.lai.civ@us.navy.mil]

Nicole Stone—Naval Information Warfare Center Pacific. [nicole.r.stone6.civ@us.navy.mil]

Stephen Dabideen—Naval Information Warfare Center Pacific. [stephen.dabideen.civ@us.navy.mil]

Krunal Amin—Naval Information Warfare Center Pacific. [krunal.amin.civ@us.navy.mil]

Michael Stuckenschneider—Naval Information Warfare Center Pacific
[michael.j.stuckenschneider.civ@us.navy.mil]

Abstract

The recent Overmatch championed Artificial Intelligence and Networks (AINet) Advanced Naval Technology Exercise (ANTX) demonstrated an alternative all-digital ANTX format enabled by integrated Rapid Innovation Labs (iRILs). This resulted in shortened ANTX planning and execution timelines, increased focus on technologies of interest, earlier integration into naval architectures, sharing of relevant operational data with participants, and meaningful feedback to developers throughout integration phases, informing research and development (R&D) and program acquisitions. An iRIL is a digital environment and an acquisition tool used to address priority Fleet needs, evaluate technologies and prototypes, and inform and influence external partner R&D investments. An all-digital iRIL can facilitate faster, smaller cycles of iterative experimentation of component technologies of interest within representative Fleet architectures and simulated operational environments. Future applications of iRILs could fundamentally change the way we acquire systems. The use of open competitive events such as an ANTX Prize Challenge could yield component level, containerized technologies of interest that are matured throughout the event process and can be assessed as well-behaved. Such well-behaved software containers or component technologies may enter the Overmatch Software Armory (OSA) or Live, Virtual, and Constructive (LVC) pipelines, achieving rapid authorities to operate (ATO), cycling to a ship within days.

Key Words: DEVSECOPS, LVC, ATO, iRIL, MOSA, Accelerated Acquisition

Introduction

Advanced Naval Technology Exercise (ANTX) events are a venue for warfighters, technologists, engineers, acquisition professionals, and sponsors to demonstrate and assess the potential of novel tactics, emerging technologies, and prototypes aligned to priority Fleet needs. ANTX events are typically hosted by Naval Warfare Centers (NWC), occasionally endorsed by a warfighting sponsor, with technologies provided by participants across the Naval Research and Development Enterprise (NR&DE), industry, and academia. The traditional approach to planning, executing, and transitioning ANTX findings has resulted in acquisition program transitions and fieldings on the order of 12–18 months or more post ANTX event. This time is typically devoted to modifications necessary for Fleet adoption (e.g., communications packages upgrades, engine modifications, ruggedization, tactics development, etc.; UAS Vision, 2018).

While ANTX's have been heralded as venues with rapid feedback loops that have resulted in some system-level procurements and have tremendously helped the U.S. Marine Corps in particular re-imagine their force structure, the pace of warfare in this century has been said to be accelerating evermore. At ANTX West 2019, Rear Admiral Donald Gabrielson, then Commander of San Diego-based Carrier Strike Group 11, spoke of the rapid change in the battle space, saying that "change is accelerating, and so we have to accelerate in order to maintain our competitive advantage" (Fuentes, 2019).

Between May 2021 and December 2021, the Artificial Intelligence and Networks (AINet) ANTX team was challenged with the audacious objective to identify and field emerging technologies at the blistering pace that maintaining overmatch over a high-tech adversary demands. The team pioneered the pairing of multiple novel concepts including leveraging innovative prize challenge acquisition authority with ANTX events, and executing technical and operational assessments in fully digital, integrated rapid innovation laboratory (iRIL) environments. These iRILs adhered to the *free, perfect, and instant* (McAffee & Brynjolfsson, 2017) key tenets of the power of the platform and were crucial to the success of the Navy's first-ever all-digital ANTX event.

An iRIL is a digital platform typically constructed of hybrid live, virtual, and constructive (LVC) environments within which emerging technologies can be easily integrated, developed, and continuously assessed. When an iRIL is developed in alignment with priority Fleet needs, and is shared widely with developers from across the NR&DE, industry, and academia, the outcome is a *shared consciousness* (McChrystal et al., 2015) and influence of internal research and development (IR&D) investments across the defense industrial base (DIB).

This shared consciousness is a state of "emergent, adaptive organizational intelligence," which fuses "generalized awareness with specialized expertise" (McChrystal et al., 2015). Noting the complex problem space and the requisite flattened knowledge dissemination required to find a solution from a systems approach, General (Ret.) Stanley McChrystal (McChrystal et al., 2015) wrote that "harnessing the capability of the entire geographically dispersed organization meant information sharing had to achieve levels of transparency" that were "entirely new" to parties involved. He was describing the basis for his *team of teams* construct in the Joint Special

Operations Task Force in Iraq in the early 2000s. This is the agile construct that Overmatch strived to achieve with the DIB via the all-digital ANTX.

In doing so, these methods improved the focus and quality of engagements with industry, non-traditional providers, and the academic community; and has driven scientific and technological investments toward technological areas of priority importance to Overmatch objectives. The application of these novel concepts was essential in enabling the speed and efficacy of technical and operational assessments for almost fifty emerging technologies submitted to AINet ANTX by industry, academic, and Navy teams.

The scope and scale of the impacts exceeded expectations. Lowering the barrier of entry into Overmatch digital platforms and providing insight into representative Fleet architectures and relevant operational environments allowed participants to quickly gain meaningful insights and near-real time detailed and quantitative assessments and feedback.

The AINet ANTX team harnessed the power of the digital platform and it became particularly profound in the context of Overmatch objectives and constraints. This audacious vision has laid the foundation and has the potential to have an even more profound impact on acquisition strategies that would strive to establish open, competitive, iRIL-powered, digitally-enabled industry engagement events on a more periodic basis.

Overmatch

Overmatch is a high priority Department of the Navy (DoN) initiative aimed at connecting platforms, weapons, and sensors together in a robust Naval Operational Architecture (NOA) that integrates with Joint All-Domain Command and Control (JADC2) for enhanced Distributed Maritime Operations. Overmatch was initiated late in 2020 with advanced capabilities already being fielded to four aircraft carriers (Katz, 2022). Additionally, the Overmatch Software Armory (OSA) and integrated LVC environments were established for the continuous integration of emerging technologies that will advance the reach, capacity, and resiliency of maritime tactical network of networks.

Yet, Overmatch is as much about delivering the NOA as it is about transforming the way that capability is delivered. The Chief of Naval Operations (CNO) Admiral Michael Gilday wrote:

> We will effectively apply modern digital and information technology to allow us to make better and faster decisions in combat and ashore, improve our readiness and sustainability, and drive affordability... Digital technologies, coupled with process improvement and an innovative mindset of continual learning, are critical to winning a future fight. (Gilday, 2021)

The end-state is not an architecture that we can specify today to meet tomorrow's needs. The end-state is about the "how" and transforming how we deliver capability. In 2020, the Secretary of the Navy (SECNAV), Kenneth Braithwaite, wrote of concerns regarding the quickly eroding advantages the United States has enjoyed as a maritime nation and provided key guidance on the path forward to retaining overmatch:

> America's creativity and innovative spirit are an enduring advantage over our rivals. Integrated investments must reinvigorate and restore an agile, modern U.S. maritime industrial and innovation base. Our efforts will draw upon traditional defense suppliers, commercial companies, and institutions at the leading edge of emerging technologies, including next generation communications, artificial intelligence, and quantum computing. (Braithwaite, 2020)

Thus, the speed and efficacy of industry engagements and science and technology (S&T) transitions are paramount to maintaining overmatch over advancing threats which are very, very real.

The AINet ANTX and associated iRILs were designed to build upon the Overmatch infrastructure and to provide the mechanism to explore emerging technologies from across the technical community. The prize challenge solicitation was open to participants from traditional defense industry and government laboratories, but also non-traditional participants from commercial industry, small business, and academia. The objective was to very quickly identify operationally relevant innovations and emerging technologies that can be easily integrated and fielded into Fleet architectures with upgrades that do not require major hull, machinery, engineering (HME) modifications or significant "hot-work" (Katz, 2022).

Approach

In creating an agile team of teams structure with the DIB, the use of a digital platform, the iRIL, was essential to accelerating the creation of a shared consciousness while capitalizing on key strengths of a digital information technology. The iRIL is a generic term for a sandbox that is sufficiently representative of the target platform that can be provided to developers to quickly develop and then confidently assess emerging technologies prior to fielding decisions.

The general advantages of an online, digital platform are its economics—that it is free, perfect, and instant and thus, begets the benefits of "near-zero marginal cost of access, reproduction, and distribution" (McAffee & Brynjolfsson, 2017). The use of digital platforms ensures an inherent modularity which can be capitalized upon to aggregate and disaggregate data, capabilities, applications, and processes at will. Further, the ability to bundle and unbundle any set of digital resources provides practical utility when the data, applications, and/or processes need to be isolated or integrated in response to sensitivity or desired scope. These "modular sets of digital resources" could be "combined and recombined" (McAffee & Brynjolfsson, 2017) and made instantly accessible, agnostic to geographical constraints, thus allowing dissemination to a much greater audience, at speeds that could not be previously achieved.

As a result, these resources could reach and be used by a singular developer or grassroots groups. This is in contrast to previous approaches, where chiefly only established entities could support the requirements of entry and subsequent development for the government. With a network delivery cost of virtually zero, this drastically reduces the barrier to contribution, providing an open hearth while maintaining necessary segregated boundaries for anyone with internet access to collaborate and contribute to the development of a solution for a dedicated problem set.

Thus, novel innovations can result, not necessarily from the direct innovation of something novel, but from the combination of materials already existing in a manner that is novel. This is the underlying theory of a process called *combinatorial innovation* (McAffee & Brynjolfsson, 2017). As stated by McAffee and Brynjolfsson (2017), "Combinatorial innovation can be fast and cheap, and when it's leveraged by the power of the free, perfect, and instant characteristics of platforms, the results are often transformative."

An advantage in the use of a digital platform is the inherent alignment to the DoD's framework for use of modular open systems architecture (MOSA) in defense acquisition programs (Deputy Director for Engineering, 2020). It is an integrated business and technical strategy which aims to achieve the incremental acquisition of "warfighting capabilities, including systems, subsystems, software components, and services, with more flexibility, competition, and innovation" (Directorate of Defense Research and Engineering for Advanced Capabilities, 2017). The bundling and unbundling feature is directly in line with MOSA in that digital platforms present forums for "highly cohesive, loosely coupled, and severable modules that can be competed separately and acquired from independent vendors" while maximizing re-use of assets alongside reducing ownership costs and risk between both parties further left of acquisition (Directorate of Defense Research and Engineering for Advanced Capabilities, 2017).

The AINet ANTX harnessed the power of the digital platform, effectively providing free, perfect, and instant (McAffee & Brynjolfsson, 2017) virtual environments to confidently assess technologies of priority interest via the AINet iRILs. These iRILs were defined by the overarching principles of digital platforms and combinatorial innovation. They were rapidly established by leveraging existing laboratory infrastructure and resources from across the NR&DE, in effect, "free." Within this greatly accelerated timeline, they were "perfect" enough, as environments were adapted to be representative within acceptable constraints of naval systems and architectures to allow for component development, with the fidelity dependent on the classification level. Lastly, they adhered to the principle of being "instant" in that iRILs were architected to be readily deployable and easy to use by third-party developers (e.g., industry, academia, non-traditional performers, etc.) with mechanisms to provide automated and instantaneous feedback. The deliberate use of an all-digital iRIL capitalized on the advantages of being able to facilitate faster, smaller cycles of iterative experimentation of component-level technologies of priority interest within representative Fleet architectures and simulated operationally relevant environments.

iRiL Foundational Technologies

Partnering with the Defense Advanced Research and Projects Agency (DARPA) and the DoN M&S Office (NMSO) was key to establishing the iRILs with minimal additional investments. Within these iRILs the AINet ANTX hosted and executed two prize challenges over a six-month period. Relevant quantitative metrics were determined within selected mission vignettes and performance was assessed automatically via the iRIL.

For the purposes of providing an in-depth case study on the use of the iRILs in conjunction with the Prize Challenge authority, the remainder of this paper will focus on the Networks iRIL. The Networks iRIL consisted of a virtual machine (VM) which was distributed virtually to participants. Participants remotely developed, deployed, and iterated their containerized algorithms within this VM and could watch how the network routing protocols within their container performed in real time in an unclassified mission vignette. Six technologies were assessed utilizing the Networks iRIL within two weeks, yielding quantitative data for comparison and assessment both at the unclassified and classified level. The unclassified results were shared with Prize Challenge participants, which can be used to guide future improvements and developments to their component technologies. This was all executed in a completely digital, distributed environment. Additional components and assessment capabilities can be added to the iRIL, an artifact that can be reused and adapted to future needs, including additional mission vignettes, adjusted for different metrics across different classification thresholds.

Naval Integrated Live, Virtual, Constructive (LVC) Environment (NILE)

LVC events are a venue for warfighters, technologists, engineers, and sponsors to demonstrate mature technologies within an operational setting with live, synthetic, or simulated systems. Live, synthetic, or simulated systems are employed to represent either red or blue forces and scenarios are typically played to mature emerging concepts of operation, assess the impact of emerging technologies, identify integration issues, etc. The naval-integrated LVC environment (NILE) is distributed across almost 20 NWCs and ranges. The various NWCs and ranges frequently run local events, but they can also connect through a distributed R&D network, which enables a distributed configuration to run scenarios as if the systems were integrated onto a single ship, e.g. communications, computers, command and control (C4I) and electronic warfare (EW) physical systems from the Naval Information Warfare Center (NIWC) based in San Diego, CA (a

C4I center of excellence), and the Naval Surface Warfare Center (NSWC) based in Crane, IN (an EW center of excellence). These entities can be integrated through the NILE to run scenarios as if the systems were integrated onto a specific ship.

In March 2019, four ANTX West technologies were integrated into the NILE virtually as either hardware or software-in-the-loop, and 24 technologies were constructively simulated. Considering most of these participants did not already have Navy contracts for their technologies, this was an extremely unique opportunity for traditional and non-traditional partners to be invited into the Naval lab infrastructure. While there were many positive outcomes from this first-of experience, most of the constructive simulations were not of high enough fidelity to make immediate fielding decisions, and less than five participants were able to meet stringent information assurance (IA) requirements to connect virtually into the NILE environment (Marine Corps Warfighting Laboratory; Naval Information Warfare Center Pacific, 2019). This experience was a tremendous success, but the approach still resulted in transition timelines of 12–18 months (or more) as a best-case scenario.

Multifunctional Information Distribution System (MIDS) Reference Implementation Lab (RIL)

In January 2019, NIWC Pacific piloted an innovative method to respond to an emergent need for Multifunctional Information Distribution System (MIDS) acquisition program office outside of traditional acquisition pathways by establishing a government-industry partnership to rapidly develop and integrate advanced waveforms.

Enabled via a Cooperative R&D Agreement (CRADA) between an industry partner and NIWC Pacific, this government-industry team prototyped a proof of concept that demonstrated successful integration of advanced waveform on a MIDS Joint Tactical Radio System (JTRS) in a Reference Implementation Laboratory (RIL). In December 2019, within 10 months, the government-industry team published a classified white paper informing of opportunities and trade-offs to integrated advanced waveform capabilities on MIDS JTRS radio. The paper also informed a classified report to Congress, released to U.S. Air Force (USAF) staff (Classified Congressional Report on LPX Capabilities, 2020).

In August 2020, the government-industry team demonstrated advanced capability of integrated waveforms and informed of the effort to several flag officers and Senior Executive Service (SES) members in the Washington D.C. area. As a result, the MIDS program office submitted a Program Objective Memorandum (POM) request to resource the capability on MIDS JTRS radio hosted on Navy tactical aircrafts (FY19 Navy Programs: Multi-Functional Information Distribution System (MIDS) Joint Tactical Radio System (JTRS), 2020). Learning about the opportunities provided by advanced waveform, in Fiscal Year (FY) 2021, the Precision Strike Weapons Program Office also initiated the formal acquisition process to onboard on their weapons platforms.

As a result of this effort the industry partners, government stakeholders, and program office were able to significantly reduce risks and shape the opportunity to meet an emergent need. This team is credited with refining the concept of establishing reference models to engage with industry and academia to mature, assess, integrate, and prototype innovations prior to formal acquisition decisions being made. If the reference models are representative enough, this approach has the potential to significantly shorten integration and Fleet transition timelines from 12 to 18 months to less than 6 months post-R&D (Amin, 2020).

Distributed Experimentation Environment (DE2)

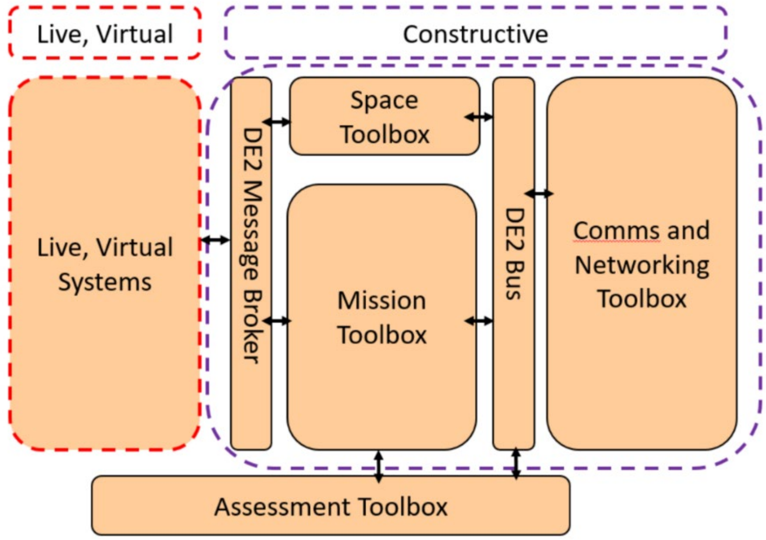

Figure 1. DARPA's Distributed Experimentation Environment (DE2)

The Distributed Experimentation Environment (DE2) is used for the testing and continuous integration and development of complex joint System of Systems (SoS) and Advanced Warfighting Architectures (AWA). The primary intent of DE2 experimentation is the development and demonstration of capabilities and technologies through the integration of constructive, virtual, and live (CVL) environments that more effectively integrate the component pieces of these constructs. The DE2 testbed provides the ability to test new concepts and technologies, provide data to assess capability and technical feasibility, and identify technical and capability gaps. The DE2 provides an avenue for continuous integration and experimentation to evolve concepts and capabilities, which delivers a risk reduction through CVL experimentation.

The DE2 architecture, as seen in Figure 1, can be broken down into two broad categories for ease of understanding. First, the DE2 contains a federation of toolboxes that integrate CVL elements to allow for broad variation in the levels of human participation and system simulation. The DE2 toolboxes are the Mission Toolbox, the Space Toolbox, the Communication & Networking Toolbox, and the Assessment Toolbox. Second, the DE2 also contains a DE2 Message Broker which allows for the integration of outside applications and other external data sources (e.g., live systems, remote sites, software-in-the-loop, human-in-the-loop) with the DE2. Figure 1 depicts the current DE2 architecture schema.

Through modular architecture, these toolboxes can be utilized either individually or federated to evaluate SoS architecture solutions. The Networks ANTX Prize challenge leveraged the Mission Toolbox (MTB) and the Communications & Networking Toolbox (CNTB).

The Mission Toolbox is an essential component to the constructive and virtual environment of the DE2. The core component is the Next Generation Threat System (NGTS). The toolbox uses threat and friendly non-deterministic behavior, weapon, system, and subsystem models for air, ground, surface, and sub-surface platforms to provide the constructive "World" state to the DE2. The toolbox provides varying levels of SoS control within the simulation, which supports the Reference Model. Non-deterministic platform behavior models are dynamic and configurable in accordance with the architecture requirements defined during experimentation planning. This was important for setting mission context in the evaluation of the solutions developed for this prize challenge.

DE2 Sigma

Sigma is a network simulator that is the backbone of the DE2 CNTB. It provides libraries of models to evaluate the effects of network technologies, algorithms, and protocols on network topologies and architectures. Unlike traditional network simulators, which requires the scenario to be defined at the start, Sigma is designed for live experimentation and platforms are added to the simulation as they are created in NGTS, without a prior knowledge. This enables support for non-deterministic behaviors that may happen during the run of a scenario in NGTS. Sigma also has the ability to connect live and virtual platforms via ethernet interface, so that those platforms can take advantage of the constructive environment being simulated in Sigma, depicted in Figure 2. This feature was heavily used for the Networks prize challenge, where the routing solutions were run in separate containers that were connected over constructive networks that were simulated in Sigma.

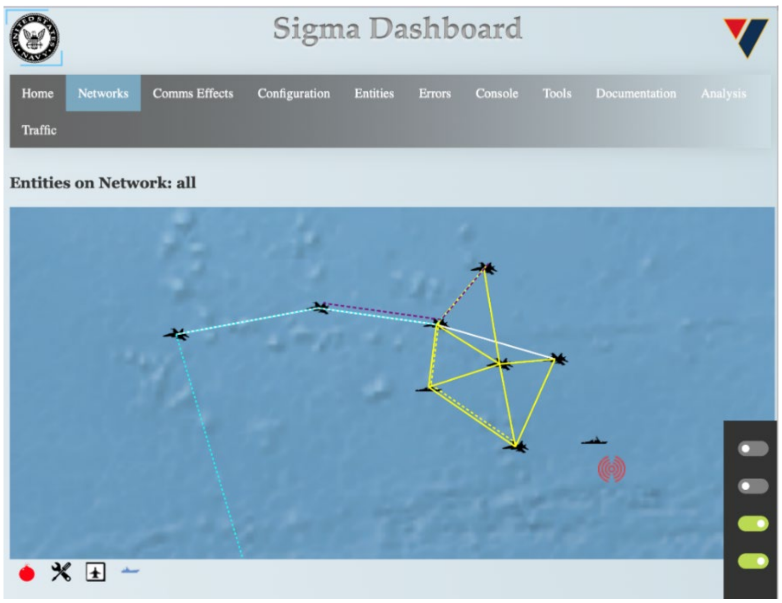

Figure 2. Sigma provides constructive networks over which live traffic is routed, giving an approximation of what would be seen in a live instantiation of the scenario being tested.

iRiL Overview and Instantiation

Given Overmatch's charter and the pace at which our high-tech adversaries are fielding new systems, we needed to reimagine our approaches to produce timelines at relevant speeds. By drawing from the lessons learned through the NILE and MIDS RIL, the concept of the iRIL was formed.

In order to be effective, the iRIL must be crafted to direct problem focus and apply boundaries to the solution space. It also must be representative enough of the target transition platform (i.e., OSA and LVC), but abstracted sufficiently as to not overshare sensitive system details, interfaces, or other sensitive or classified information. Figure 3 depicts the particular instantiation of the Networks iRIL, which took a "slice" of LVC capabilities, packaged and shared with developers within a secure Simulation Based Environment (SBE) with automated feedback. In turn, the products derived from this exchange could be plugged back into the entirety of the LVC grid and evaluated within a larger SoS context.

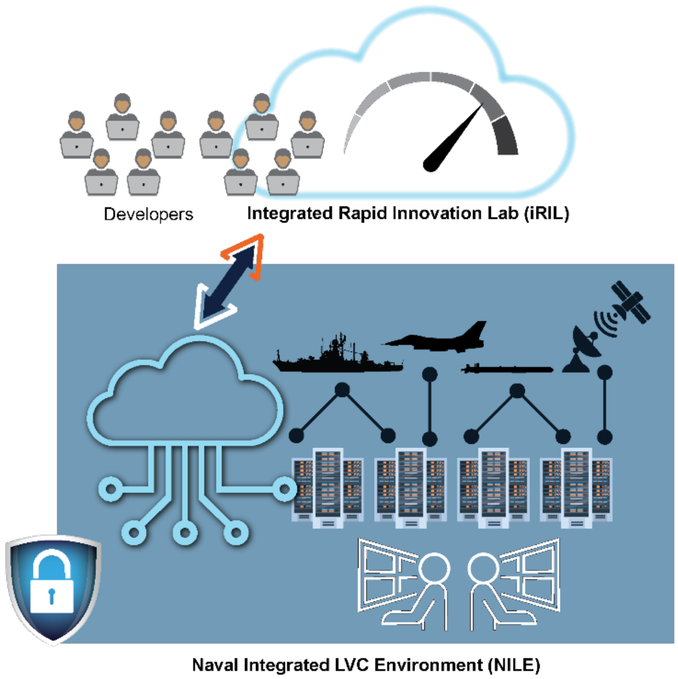

Figure 3. Graphical Representation of the iRIL

The design and use of a developer deployable iRIL offers several advantages over the traditional approach where the product is designed and developed in isolation of the target platform and integrated later, including:

(1) The iRIL allows the specification of the problem statement and defines the boundaries in which the solution must operate, more concretely than an abstract description. This allows industry to focus on primarily solving the issue at hand, without adding extra features which may or may not be of interest.

(2) The iRIL should provide a reasonable approximation for the target platform, and this leads to quicker and easier transitions.

(3) The fact that it is deployable to developers makes it easier for our industry partners to develop and test in their own space and at their own rate, rather than relying on government resources for integration and testing events.

(4) Lastly, the inclusion of integrated performance analysis into the sandbox increases the pace of the development cycle and allows for rapid tuning of the system being developed, within the problem scope.

To achieve the accelerated timelines, it is important to leverage existing technologies to build the desired sandbox. As previously mentioned, the AINet ANTX iRILs leveraged more than 5 years of DARPA's investments that have expanded the NILE framework into DE2. Leveraging the communications and networks toolbox enabled the rapid timeline from solicitation to prize award.

The Networks iRiL

Leveraging the DE2, the Networks iRIL was created as an SBE that employed tactically-relevant scenarios in operationally-relevant conditions. This iRIL was designed with a very narrow focus: to evaluate routing protocols. It was constructed in such a way that the ANTX participants only needed to install their routing solution in a given container, and then they could run the experiments and look at the performance results based on post-process analysis. It is critical that the iRIL be easy to operate given the short timeline for development and integration. With the Networks iRIL, the process was greatly automated, the routing solution could be evaluated with only a few clicks, and without necessarily understanding the components of the iRILs or how they interoperated.

Execution and Outcomes

The 2021 all-digital AINet ANTX, powered by digital platforms (i.e., iRILs), offered an alternative ANTX approach that resulted in:

- Shortened ANTX planning and execution timelines
- Increased focus on specific components of interest within digital representations of naval systems and architectures with well-defined metrics and automated assessments
- Earlier integration of technologies into relevant naval architectures
- Sharing of relevant operational data with developers
- More meaningful feedback to developers throughout integration phases to inform R&D and drive program acquisitions
- Ease of evaluating technologies in operationally relevant scenarios
- Mission relevant assessments upfront

Shortened ANTX Planning and Execution Timelines

The Project Overmatch established LVC environments and DEVSECOPS powered software development pipelines were essential to enabling the rapid and iterative integrate, test, field, *and* learning cycles. The OSA and our implementation of DEVSECOPS is key to rapidly delivering new capability. The iRILs were built directly upon the key infrastructure pieces and demonstrated the ability to deploy next-generation networking and ML/AI tools at speed. Figure 4 shows the marked difference in execution and planning cycles for traditional ANTX compared to digital ANTX, and the requisite level of effort measured in manpower in order to execute.

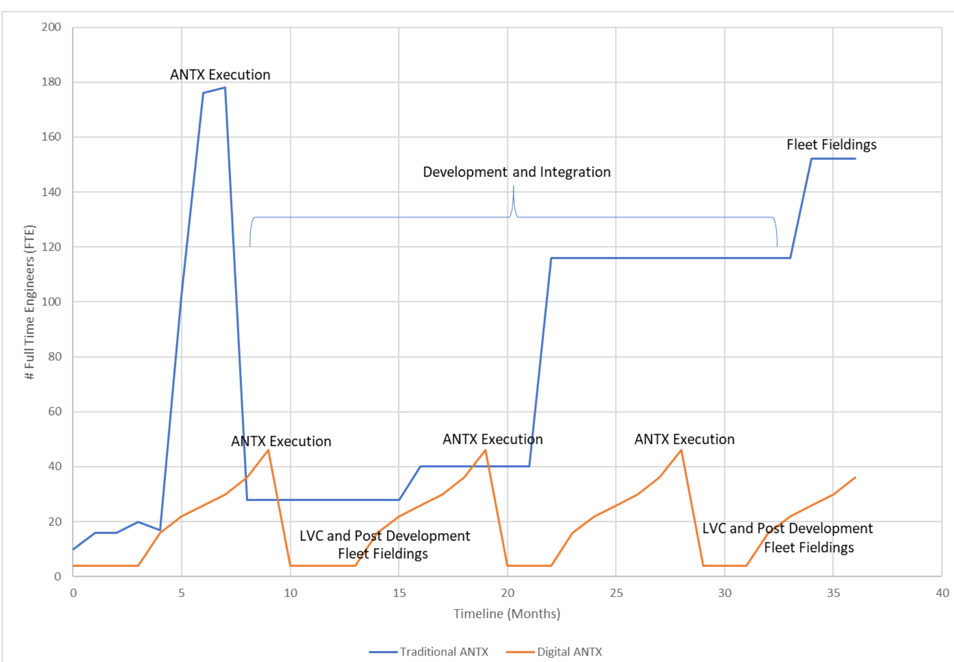

Figure 4. ANTX Approaches—Timeline Comparison

Increased Focus on Specific Components of Interest With Well-Defined Metrics and Automated Assessments

The goal of the Networks prize challenge was to find efficient routing protocols that can operate in dynamic, low-capacity networks. The iRIL and assessment criteria focused on technologies that contribute specifically to the Open Systems Interconnection model (OSI model) network or application layer. The OSI model defines the functionality of the network layer as structuring and managing multi-node network, including addressing, routing, and traffic engineering (X.220, 2008). Solutions were required to run in a Linux (Centos8) container, with potentially multiple Ethernet interfaces. Solutions were expected to control how application packets were forwarded, queued, or dropped on a per-packet or per-flow basis. Technologies that operated above layer 3 (e.g., application layer routing protocols), but manipulated the routing tables or captured and redirected traffic to interfaces, were considered within scope. Solutions that leveraged Software Defined Networking (SDN) technologies or Mobile Ad-hoc Networking (MANET) solutions were encouraged.

The Networks iRIL and assessment criteria for this challenge focused specifically on improvements to network routing protocols for highly-distributed, highly-contested, low-bandwidth, and low-latency networks. The novel prize challenge approach, sophistication of the iRIL, and speed of execution, provided the Overmatch team unmatched insight into commercially developed technologies and innovations that improved the performance of extremely limited Maritime network conditions characterized by sparsely connected nodes, multi-hops, and low bandwidth links with dynamic and unpredictable connectivity.

Solutions solicited were required to provide efficient, low-overhead routing of application packets. As Figure 5 shows, the metrics looked at packets delivered, overhead, latency, and mission impact. The definition of these metrics and the post-run analysis which quantified the performance of the routing protocol with regards to these metrics, focused our industry partners on the problem via optimization of the resulting performance evaluation. The post-run analysis in the Networks iRIL gave insight at multiple levels an overall assessment to flow-level to packet-level metrics.

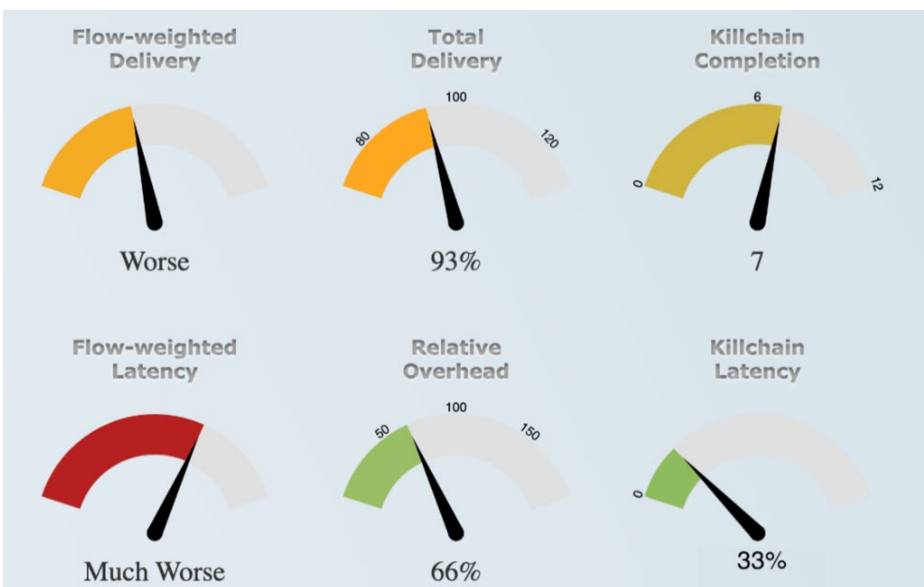

Figure 5. Sample Output From the Post Analysis in the Networks iRIL Showing the Performance Relative to the Baseline

Even though there are many text artifacts available to speak to this challenge area (i.e., Information Warfare (IW) Science and Technology Objectives (STOs), PEO C4I S&T Gaps, AINet ANTX Prize Challenge announcement, etc.), the participants admitted they did not fully grasp the complexity or difficulty of the technical challenge that the Maritime networks scenario presents until they tried to get their routing protocol working in the Networks iRIL.

Earlier Integration of Technologies Into Relevant Naval Architectures

In the end, the winner extracted their routing protocol from a commercial hardware specific implementation and was successful in demonstrating performance improvements through innovations. This was a great result, as the resulting solution, the extracted routing protocol, is something that is more useable than the hardware/software integrated product the vendor would usually try to market. The use of the iRIL provided well defined boundaries of the solution space: it had to run on a standard Linux installation, and had to route application packets using the Linux routing table. This excluded full-stack or custom hardware solutions that would be much more difficult to integrate, evaluate, and eventually field. Instead, the participants needed to deliver a containerized, workable solution which greatly eases the transition pathway.

Sharing of Relevant Operational Data With Developers

The AINet ANTX lowered the barrier of entry to access relevant Fleet architectures and data sets. Operationally relevant and training-quality data sets were made available to industry and academic participants across both prize challenges within the ANTX.

While the Networks prize challenge has been largely the focus within this paper, the authors would like to note how the AI prize challenge in particular lowered the barrier of entry into the OSA. Participants were given access to a secure government-owned cloud environment, datasets for training AI models, and drove the development of the very first version of the Overmatch AIOps development pipeline. Prior to the AINet ANTX, access to these tools and datasets was limited to current contractors with Common Access Cards (CACs), and in many cases required active contracts and security clearances. The development of the AI iRIL significantly lowered the barrier of entry and granted access to a wider variety of participants who were still all U.S. citizens for the purposes of competing in the prize challenge. The AIOps development pipeline was conceived, developed, and provisioned to participants in less than 2 months' time. Without this innovation, more than 70% of the invited participants would have been precluded from participating in the AINet ANTX event. During assessments, the operational impact of the innovative approaches and solutions were of particular interest and the Fleet assessors provided valuable insights to the technical assessors and participants alike.

More Meaningful Feedback to Developers Throughout Integration Phases to Inform R&D and Drive Program Acquisitions

This experience inspired this non-traditional industry provider to continue to invest their discretionary or internal R&D (IR&D) investments and to explore software-focused business models. The team of government experts responsible for the development of the Networks iRIL and overall AINet ANTX orchestration also inspired other industry participants to recognize the DoN's interest in this specific technical area and shift IR&D investments into an area which had been dormant for over 10 years, at least in the case of one of our more traditional industry partners. Further, the technical focus and difficulty of the challenge continues to be highly motivating to all participants. All AINet ANTX participants, and many others who have since heard about the novel Networks iRIL approach, have expressed interest in participating in future experiments where this iRIL can be made available to assess improvements to network routing protocols.

Mission Relevant Assessment Upfront

New technologies are only relevant if they enable the mission objectives sought by the Navy. Yet, this gap is particularly difficult to fill by both academia and industry as they lack adequate insight into what the Navy is trying to achieve, due to the sensitive nature of the matter. Traditional acquisitions methods would outline the desired capabilities, but leaves much room for interpretation. With AINet ANTX, the mission relevance was built into the iRIL by capturing it in the problem formulation and in the metrics used for evaluation. For example, the Networks Challenge sought an efficient routing protocol, and there are many ways to achieve routing packets in the system. However, to be relevant in the intended system, the routing must be done by updating the Linux routing table. Furthermore, NGTS was used to model the mission, and its inclusion ensured evaluation in the context of Navy missions. To handle the sensitivity of the mission relevance, there were two classes of scenarios—classified and unclassified. The unclassified scenario gave a "fuzzy" view of how the technology would be used in the broader system, in a sample mission that does not reveal sensitive information. The classified scenario, however, leveraged DARPA mission scenarios, which allowed better evaluation of the mission impact while following the same principles as the unclassified scenario in terms of execution and evaluation. This approach allowed the evaluation of the technologies in the context of missions, ensuring the result would have a positive impact on Navy missions.

Conclusions

In demonstrating the power of the platform at the blistering pace of Overmatch, the AINet ANTX team's approach and findings have challenged the defense acquisition community and our defense industry primes to think bigger and beyond the constraints of today's approaches, architectures, and acquisition strategies.

Overmatch is the DoN's priority initiative to connect naval assets (e.g., ships, aircraft, weapons systems, sensors) into a coherent NOA. The AINet ANTX proved successful in rapidly identifying cutting-edge technologies and innovations from non-traditional partners that could be immediately integrated into the NOA. The AINet ANTX team's efforts resulted in the award of four prize challenges, which were recognized as exemplar and critical to the success of the first-ever all-digital, Overmatch-championed ANTX event. The team embraced this initiative with objectivity and a sense of commitment that will have a lasting effect on the quality, feasibility, and transition probabilities of these, and future, technologies and innovations by:

(1) Demonstrating the power of the digital platform

(2) Establishing mechanisms for more effective collaborations between technology providers, resource sponsors, and program offices much earlier in the acquisition process

The team's success is leading Overmatch to pursue additional iRILs and ANTX events to address other priority S&T needs. Additionally, the AINet ANTX team is responsible for shifting industry internal R&D (IRAD) investments in areas of key interest to Navy priority programs.

The benefits and results of iRILs are not limited to theory; the AINet ANTX event is proving out and testing iRIL potential and promises. Rapid identification, maturation, continuous assessment, transition, and ultimately **fielding to the warfighter** are the promises upon which iRILs must deliver. There are multiple ongoing efforts to:

(1) Continue development of technologies demonstrated within the prize challenge

(2) Advance the capability and scope of the Networks iRIL itself

(3) Leverage the Networks iRIL for other LVC events and continuous testing

(4) Develop additional iRILs in other areas of priority interest

ANTX Follow-On Technology Development

The ANTX event was executed under the Prize Challenge Authority (15 U.S. Code § 3719) with cash awards going to first place and second place winners. The prize incentivized industry and the broader NR&DE to participate and integrate into iRIL environment, and was structured in a way to enable follow-on sole-source award under a variety of authorities. Upon completion of assessments, announcement of winners, and distribution of final participant reports, the team reviewed each participant's technology and demonstrated capability to identify ideal next steps. Due to the compressed timeline, many technologies did not demonstrate a level of maturity that supported immediate government investment. As a result, CRADAs were being pursued at the time of writing this report. CRADAs will allow industry to continue development within the government-furnished iRIL, providing industry access to the relevant naval data, architectures, and vignettes. After the technologies reach maturity, prototype OTAs will be directly awarded to the technologies that demonstrate best value to the Navy. Currently the team is discussing possible prototype OTA award in FY2023. The team is unsatisfied with this timeline. Based on lessons learned and organizational relationships being established, future technologies developed and demonstrated within iRILs should be able to transition into prototype OTAs almost immediately after the conclusion of an iRIL-hosted ANTX event. The AINet ANTX team demonstrated that these timelines are possible and that there are no technical limitations in achieving this bold vision.

iRIL Development

A tangible outcome from the AINet ANTX was the strong desire to further develop the iRILs themselves. Multiple stakeholders and organizations have gained a strong appreciation for the iRIL concept, each with their own equities and expertise in identifying and assessing emerging technologies. Each stakeholder group may establish new and different tools and features within the iRIL itself. In the future, iRILs may be developed as part of acquisition programs with direct support from prime contractors to engage wildly with the broader DIB as systems are developed.

Future prize challenges will focus on the other OSI layers (application through physical layers) and/or technology areas which include—but are not limited to—communications, networking, unmanned systems, weapons systems, modern software development pipelines and infrastructure, underlying data architectures, and rapid deployment of automation, machine learning (ML), and artificial intelligence (AI) into tactical applications both afloat and ashore.

Acquisition Impacts of Digital ANTXs Enabled by iRILs

The Networks and AI iRILs built directly upon key infrastructure pieces and demonstrated the ability to deploy next-generation networking and AI/ML tools at speed. This has the potential to set a new standard not only for ANTX events, but for acquisition programs as well.

As more and more of the DoN acquisition programs adopt Overmatch key tenets of modern containerized architectures and MOSA approaches, the engineering development models and fielded systems become the iRILs. In this manner, the resultant technologies could be considered *well-behaved*, i.e., developed and containerized in Navy-approved DEVSECOPS software pipelines and can satisfy Risk Management Framework (RMF) Rapid Assess and Incorporate Software Engineering (RAISE) application integration requirements. Acquisition programs can utilize this mechanism to directly drive effective and recurring series of industry engagements to field technologies at a blistering pace.

This speaks to the demand-side economies of scale, also known as a *network effect* (McAffee & Brynjolfsson, 2017), where certain commodities increase in value as usage increases. The economics of the network effect are "central to understanding business success in the digital world" and "were worked out in a series of papers in the 1980s" (McAffee & Brynjolfsson, 2017). Fundamentally, acquisition professionals will need to consider network effects on the acquisition processes, cultural behaviors, and desired outcomes across the information and technical domains. Use of the construct of iRILs can lead to successful implementation of MOSA. The MOSA Reference Frameworks in Defense Acquisition Programs noted:

> Acquisition programs using MOSA as a foundational practice have achieved a degree of modernization (e.g., technology refresh, inclusion of innovative technology); cost savings (e.g., cost avoidance, savings realized from increased competition); and interoperability. If programs are organized to incorporate MOSA, then MOSA reference frameworks can enable DoD engineering and business communities to structure technology investments, upgrades, and innovation opportunities for insertion into programs during design and at regular refresh cycles. (Deputy Director for Engineering, 2020)

The use of open competitive events such as an ANTX Prize Challenge could yield component level, containerized technologies of interest that are matured throughout the event process and can be assessed to be well-behaved within representative Fleet architectures and relevant to operational environments. Such well-behaved software containers or component technologies may enter the OSA or LVC pipelines, rapidly achieve authority to operate (ATO), and cycle to an operational unit within days (not months or years).

Next Steps and recommendations

While the overall execution of the inaugural Overmatch AINet ANTX was a success, much remains to be done in order to further the goals of Overmatch S&T efforts as a whole, as well as accelerate Fleet adoption of S&T (FAST). To that end, the team recommends the following:

ANTX timeline recommendations. The protocols demonstrated in the Networks iRIL and the algorithms deployed to the AI iRIL were just the start. Many of the technologies remain TRL 4 or 5. We believe a period, of not less than 6 additional months, should be allowed for each of the participants to further mature their technologies with continued guidance and technical direction from Overmatch S&T entities. This could be done leveraging IRAD, SBIR, CRADA, and other mechanisms to be codified in the FAST framework.

Further iRIL development. The demonstrated iRIL capabilities proved to be an effective tool for quick assessments of technology readiness and applicability to operational scenarios of relevance, particularly with the Networks Prize Challenge. Even with the AI Prize Challenge, the AI iRIL, though in its infancy, proved to be quick to set up within the overall 6-month time constraint. Both iRIL's demonstrated value in getting a protected, controlled, and unclassified level digital sandbox environment which attracted non-traditional partners' interest in experimentation with and for Overmatch priorities. Advancing current iRIL capabilities could include expansion of the Networks iRIL to include dynamic scenarios which can walk through an operational scenario and be modularized and integrated into existing Navy LVC infrastructure and DoN M&S. Further iRIL development should be aligned to Overmatch priority needs but also responsive to areas of significant DIB, commercial, or other R&D investment, where the available technologies options are identified to be dense and diverse (Jackson et al., 2018).

Drive Overmatch aligned acquisition programs to iRIL constructs to identify emerging technologies. The event itself proved to be a useful gatekeeping function for the Overmatch team, as many prospective DIB partners are still proposing innovations at the system-level, as opposed to component or container-level innovations. Use of iRIL's in Overmatch hosted events provides a publicized venue for Overmatch to engage with prospective external partners, and rapidly assesses technologies aligned to Overmatch needs that could be fielded very quickly.

Accelerate the Fleet Adoption of S&T. The Overmatch S&T acquisition approach began as a theory, but the event execution proved useful to accelerate the FAST. However, much of the approach post-S&T event remains to be fully defined and demonstrated. The first of its kind event proved out certain key aspects, including focusing iRIL development and ANTX solicitation to priority Overmatch needs, and collaborating with transition sponsors early in the development process. The team recommends further refinement with input from Overmatch internal and external stakeholders to codify a FAST framework and establish deliberate pathways with the requisite funding and requirements flexibility to field emerging technologies into future fielded baselines.

References

Amin, K. (2020, September). Advanced Tactical Data Link (ATDL) Reference Implementation Lab. Naval Information Warfare Center Pacific.

Braithwaite, K. J. (2020). *Advantage at sea.* Office of the Secretary of the Navy.

Classified Congressional Report on LPX Capabilities. (2020, May).

Deputy Director for Engineering. (2020, May). Modular Open Systems Approach reference frameworks in defense acquisition programs. Office of the Under Secretary of Defense for Research and Engineering.

Directorate of Defense Research and Engineering for Advanced Capabilities. (2017). Modular Open Systems Approach. Undersecretary of Defense for Research and Engineering. https://ac.cto.mil/mosa/

Fuentes, G. (2019, April 14). *Navy, Marines exercising how to use information warfare in future conflicts*. (USNI News). https://news.usni.org/2019/04/12/navy-marines-exercising-how-to-use-information-warfare-in-future-conflicts

FY19 Navy Programs: Multi-Functional Information Distribution System (MIDS) Joint Tactical Radio System. (2020, January). *2020 Annual Report*. Office of the Director, Operational Test and Evaluation.

Gilday, M. M. (2021). *NAVPLAN 2021.* Office of the Chief of Naval Operations.

Jackson, C., Sansone, A., Mercer, C., & King, D. (2018, May 9–10). Application of set-based decision methods to accelerate acquisition through tactics and technology exploration and experimentation (TnTE2). *Proceedings of the 15th Annual Acquisition Research Symposium.*

Katz, J. (2022, January 25). Four carriers being prepped for Navy's Project Overmatch. *Breaking Defense.* https://breakingdefense.com/2022/01/four-carriers-being-prepped-for-navys-project-overmatch/

Marine Corps Warfighting Laboratory & Naval Information Warfare Center Pacific. (2019, April 9). Advanced Naval Technology Exercise (ANTX)—West Fight the Naval Force Forward (FNFF) FINEX. DoN.

McAffee, A., & Brynjolfsson, E. (2017). *Machine platform crowd.* W. W. Norton.

McChrystal, S., Collins, T., Silverman, D., & Fussell, C. (2015). *Team of Teams.* Penguin.

UAS Vision. (2018, July 31). *Martin UAV—Naval Air Systems Command Sign Contract*. https://www.uasvision.com/2018/07/31/martin-uav-naval-air-systems-command-sign-contract/

X.220. (2008, December 10). *Use of X.200-Series protocols in CCITT Applications*. International Telecommunications Union. https://www.itu.int/rec/T-REC-X.220-198811-S/en

Acquisition Research Program
Naval Postgraduate School
555 Dyer Road, Ingersoll Hall
Monterey, CA 93943

www.acquisitionresearch.net