EMERGING TECHNOLOGIES INSTITUTE | NDIA

Enabling the Joint Warfight

Challenges & Opportunities

Winning the Joint Warfight Report • November 2023
NDIA Emerging Technologies Institute

Contributors

NDIA ETI

Writing Team

The Honorable Alan Shaffer
ETI Distinguished Visiting Fellow

Wilson Miles
Associate Research Fellow

Executive Director

Dr. Arun Seraphin

Special thanks to the ETI staff for their feedback throughout the duration of this workshop report.

External Contributors

Dan Patt
Senior Fellow, the Hudson Institute

Balasubramaniam (Ravi) Ravichandran
Vice President & Chief Technology Officer,
Intelligence & Security, BAE Systems, Inc.

Guy Walsh
Executive Vice President and COO, NDIA

Jim Keffer
Vice President, Future Concepts, Lockheed Martin

November 2023
First published in 2023 by NDIA's affiliate, the Emerging Technologies Institute. 2101 Wilson Blvd, Suite 700, Arlington, VA 22201, United States of America. (703) 522-1820

This report is made possible by general support to NDIA and the Emerging Technologies Institute. No direct sponsorship contributed to this report. This report is produced by NDIA, a non-partisan, non-profit, educational association that has been designated by the IRS as a 501(c)(3) nonprofit organization – not a lobby firm – and was founded to educate its constituencies on all aspects of national security. Its research is nonpartisan.

For more information please visit our website: EmergingTechnologiesInstitute.org

Written by The Honorable Alan Shaffer and Wilson Miles.

Typeset and produced by Hannah Meushaw, Alexander Feeser, and Eve Dorris.
Edited by Jacob Trask.

MEDIA QUERIES:
Habiba Hamid, Director of Public Affairs & Communications at hhamid@NDIA.org

Table of Contents

Executive Summary

The geopolitical landscape and changing nature of war – largely driven by technology – requires a shift in approach to warfighting. Historically, the United States' military has fought in stovepipes; each service is responsible for its own domain (air, sea, land, space, and cyber) and operates its systems discretely. Communication across services and domains was limited, if not absent in many operational cases. Now, China's military modernization efforts and growing capabilities force the U.S. to transform how it fights; the U.S. must adapt to these evolving conditions. The Joint Chiefs of Staff recognized the need for the Department of Defense and each military service to modernize or face the prospect of conventional military defeat. In response, DoD created the Joint Warfighting Concept (JWC), which is defined as a threat-informed, operational concept that provides an overarching approach to how the Joint Force will operate and fight as a team across all domains.[1] The JWC guides operations, activities, and investments throughout DoD by providing a common goal for the armed services. It is also intended to inform how DoD partners across industry and the interagency community can support joint warfighting efforts.

The vision outlined by the JWC is not new. There have been multiple iterations of joint documents: in 1996, DoD released *Joint Vision 2010*; in 2005, DoD released the *Capstone Concept for Joint Operations 2.0*, and; in 2012, DoD released the *Capstone Concept for Joint Operations: Joint Force 2020*. All versions have overlapping ideas, such as a globally integrated or flexible Joint Force and cross-domain synchronization. The primary difference between the JWC and previous versions is that new technologies, such as a DoD-hybrid cloud environment, may enable DoD to truly achieve its joint objectives.

In 2022, the National Defense Industrial Association's (NDIA) Emerging Technologies Institute (ETI) convened four workshops on the Joint Warfighting Concept with a session on each of the four Imperatives. Hosted by the Honorable Al Shaffer, each session posed a series of questions to the panelists, who spoke from their respective positions in senior leaderships in government and industry. For each panel, the core talking points focused on several areas, including:

1. What each Strategic Imperative is attempting to achieve
2. What technical or engineering efforts are underway to meet the identified capabilities needed
3. What barriers would prevent DoD from being successful within each Strategic Imperative

Key Takeaways

1. New technologies are providing DoD with the opportunity to achieve JWC's envisioned goals, which will differentiate JWC from previous visions for the Joint Force.

2. Industry works across the DoD, so OSD and the services need to clearly communicate what capabilities they want, as the solutions to the challenges the JWC articulates will be a combined government-industry effort.

3. If the goals of the JWC are achieved – such as faster decision-making loops, synchronized fires, and route optimization – the benefits will extend beyond the Indo-Pacific Command into the other geographic commands.

Key Recommendations

1. The Department of Defense should publish an unclassified version of the Joint Warfighting Concept.

2. The Department of Defense should integrate space-based assets from the defense agencies and intelligence community into decision-making networks for warfighters.

3. The Department of Defense should continue to push for the adoption of modular open-system architectures, digital materiel management, and digital engineering practices.

4. The Department of Defense should continue to invest in Modeling and Simulation (M&S) tools to support the development, integration, and transition of next-generation solutions.

1 Milley, General (Ret) Mark A. "Strategic Inflection Point: The Most Historically Significant and Fundamental Change in the Character of War Is Happening Now— While the Future Is Clouded in Mist and Uncertainty." National Defense University. JFQ 110, 3rd. Quarter 2023. https://ndupress.ndu.edu/Portals/68/Documents/jfq/jfq-110/jfq-110_6-15_Milley.pdf?ver=XE5o7a8f80Ro99ue8Vh-IQ%3d%3d

Introduction

In Summer 2021, the Emerging Technologies Institute (ETI) of the National Defense Industrial Association (NDIA) held the Institute's launch with keynote speaker Gen John Hyten, USAF (Ret), then the 11th Vice Chairman of the Joint Chiefs of Staff. Hyten noted that, in a series of wargames culminating in October 2020 simulating an invasion of Taiwan by the People's Republic of China in the time frame 2027-2030, existing United States DoD warfighting concepts "failed miserably."[2] According to one defense official, "gathering ships, aircraft, and other forces made them sitting ducks."[3] These games were conventional in focus but did account for variables involving cyber warfare.

The wargames acknowledged several significant advancements by the PRC from 2015 to 2025. First, for many years, the U.S. enjoyed air dominance over any air force in the world, largely due to its fifth-generation air fleet. However, the assumption that the U.S. will still have air dominance in 2025 is in question, as the Chinese began fielding their own indigenous fifth generation fighter, the J-20, soon followed by the J-31. Both will be fielded at scale by 2025. Second, the Chinese have spent a great deal of time and money developing what is largely regarded as the best Coastal Integrated Air Defense network in the world, to include systems such as the HQ-9B, which has a range of 250 km.[4] This capability could severely hinder any U.S. airborne battle management. Third, in recognition of the great capability the U.S. Navy possesses in the region, the Chinese developed a very deep magazine of short, medium, and long-range ballistic missiles. These systems – particularly the DF-21 and DF-25 – can, in theory, prevent the U.S. surface fleet from contesting a short-range fight. The shorter-range DF-21 has an operational range of about 1,700 km, while the DF-25 warhead can reach targets 3,200 – 4,000 km away.[5] According to the 2023 Department of Defense China Military Power Report, China's long-range precision strike and hypersonic weapon capabilities are designed to reach foreign military bases and fleets in the Western Pacific.[6] Additionally, in 2007, the Chinese demonstrated the ability to successfully shoot down satellites in low earth orbit (LEO), and the prevailing assumption of military experts is that, by 2025, they could engage satellites in Geo-stationary orbits.[7] Since a conflict in the Indo-Pacific region would involve primarily air and naval forces, the novel capabilities developed by China could deplete U.S. air assets, forcing the Navy to engage at longer ranges. The Chinese, as Gen. Hyten said, have spent 20 years studying the U.S. and have tailored their capabilities to counter U.S. advantages.

Given the imperative for PRC leaders to modernize the PLA's capabilities across all warfare domains and the ability to move enough U.S. combat forces into any Southeast Asia fight – like would be the case with Taiwan – would be daunting.[8] The Pacific Ocean is expansive, with limited land masses by which to stage troops, platforms, and munitions. Proximity to the potential conflict zone is instrumental for the U.S.' ability to effectively conduct operations. Moreover, the Chinese are rapidly expanding their capability in a theater that does not favor an expeditionary force.

Retired General Hyten and the rest of the U.S. senior DoD leadership concluded that the ability to knit U.S. forces together as a joint force has some current limitations. This realization led to the Joint Chiefs of Staff to create the Joint Warfighting Concept (JWC) and its "Strategic Imperatives" to effectively conduct Joint All Domain Operations. The JWC is a multi-year effort to "develop a comprehensive approach for joint operations against future threats and provide a guide for future force design and development."[9] Referencing the failure to produce a victory in the wargames, Gen. Hyten emphasized the need to refocus and figure out, asking, "How do I aggregate my capabilities to provide significant effect, and then how do I disaggregate to survive any kind of threat?" In simplest terms, the operational need is a joint U.S. force, with allies and partners, that effectively commands, controls and communicates; coordinates integrated cross-service component fires; rapidly fuses information into decision advantage, and resupplies the force in contested environments. This led to the four JWC Strategic Imperatives:

1. Joint All-Domain Command and Control (JADC2)
2. Joint Fires
3. Contested Logistics
4. Information Advantage

These four imperatives begin the process of moving the DoD from a force that aggregates (masses) to fight to one that is distributed and agile. Instead of having all assets concentrated, the goal is to complicate targeting for the adversary. Gen. Hyten characterized these four initiatives in the July 2021 kickoff of the National Defense Industrial Association's Emerging Technologies Institute (ETI), when he said the following about each[10]:

---

2 Copp, Tara. "It Failed Miserably": After Wargaming Loss, Joint Chiefs are Overhauling How the US Military will Fight." Defense One. July 26, 2021. https://www.defenseone.com/policy/2021/07/it-failed-miserably-after-wargaming-loss-joint-chiefs-are-overhauling-how-us-military-will-fight/184050/

3 Ibid.

4 "Hong Qi 9 (HQ-9) Air Defence Missile System." Army Technology May 28, 2021. https://www.army-technology.com/projects/hong-qi-9-hq-9-air-defence-missile-system/.

5 "DF-25 - China Nuclear Forces." Accessed August 2, 2023. https://nuke.fas.org/guide/china/theater/df-25.htm.

6 "Military and Security Developments Involving the People's Republic of China." Annual Report to Congress. U.S. Department of Defense, 2022. https://media.defense.gov/2023/Oct/19/2003323409/-1/-1/1/2023-MILITARY-AND-SECURITY-DEVELOPMENTS-INVOLVING-THE-PEOPLES-REPUBLIC-OF-CHINA.PDF.

7 Mowthorpe, Matthew and Trichas, Markos. "A Review of Chinese Counterspace Activity." The Space Review. August 1, 2022. https://www.thespacereview.com/article/4431/1

8 Lt Col Georgulis, Grant "SWAT". "Winning in the Indo-Pacific Despite the Tyranny of Distance: The Necessity of an Entangled Diarchy of Air and Sea Power." Air University. August 1, 2022. https://www.airuniversity.af.edu/JIPA/Display/Article/3111131/winning-in-the-indo-pacific-despite-the-tyranny-of-distance-the-necessity-of-an/.

9 Heckmann, Laura. "Joint Warfighting Concept 3.0 'Definitely Coming,' Official Says." National Defense Magazine. April 5, 2023. https://www.nationaldefensemagazine.org/articles/2023/4/5/joint-warfighting-concept-30-definitely-coming-official-says.

10 "Joint Chiefs of Staff Vice Chair on Defense Technology | C-SPAN.org." Accessed August 2, 2023. https://www.c-span.org/video/?513684-1/joint-chiefs-staff-vice-chair-defense-technology.

JADC2: The Pentagon's push to connect everything demands always-on, hackproof networks. Gen. Hyten said, "The goal is to be fully connected to a combat cloud that has all information that you can access at anytime, anyplace. You can pull it all together and, with all-domain command and control, figure out the best data and be able to act quickly on that."

Joint Fires: The idea behind Joint Fires is to enable fires to come from all domains and all Services. The goal is for the Services to act at the same time under a single command structure, allowing U.S. forces and firepower to "aggregate" to attack, then rapidly disperse, thereby surviving adversary long-range fires from all domains.

Contested Logistics: Resilient logistics in the Indo-Pacific region requires new and creative ways to deliver fuel and supplies to the front lines. U.S. Transportation Command and the Air Force are "working on rockets and a space trajectory to get a large cargo spaceship into and out of battlefields." While this statement came from Gen. Hyten, he undersold the difficulty of logistics for several reasons:

1. There are few forward bases with enough defense to be a distribution point
2. The surface fleet is vulnerable to long-range precision strikes
3. Communications are not assured in a contested electromagnetic environment

Information Advantage: Information Advantage underpins the other three Strategic Imperatives; it should be understood as gaining a temporary edge by using information through technical systems, cognitive processes, and psychological influence to achieve tactical, operational, or strategic advantages against a competitor.[11]

In late August 2023, the Joint Chiefs of Staff published Joint Warfighting 3.0, or Joint Publication 1 Volume 1, which demonstrates that the JWC is maturing from concept to doctrine; While the JWC is not publicly available online, former Chaiman of the Joint Chiefs of Staff, General Mark Milley, outlined seven key tenets of the JWC in a 2023 National Defense University article: Integrated, Combined Joint Force; Expanded Maneuver; Pulsed Operations; Integrated Command, Agile Control; Global Fires; Information Advantage, and; Resilient Logistics.[12] The seven key tenets, which overlap JWC's preceding four Strategic Directives, are intended to influence each service's force design and development efforts. In his article, now retired Gen. Milley states that the next step is to create a leadership structure that turns concepts into capabilities.

ETI Winning the Joint Warfight Panels

To further explore these concepts, NDIA's ETI hosted a series of four moderated panels – all with senior personnel. The panels were moderated by Alan Shaffer, Distinguished Visiting Fellow at ETI, and were composed of an operator; an acquisition lead, a technology lead, and often a fourth individual to complement the discussion.

Each panel addressed a series of questions, intended to explore the opportunities and challenges of developing enhanced joint warfighting capabilities for future operations. In the below list, X represents the capability area being examined (JADC2, Joint Integrated Fires, Contested Logistics and Information Advantage):

Panel Questions

- What is X trying to achieve, and how will this be different than the capabilities that exist today?
- How will the capabilities of X enhance DoD capabilities against a wide diversity of threats?
- What are the underlying technological, doctrinal or organizational areas that will need to be addressed to enable capability X?
- What are the critical tasks associated with capability X that cannot be addressed today?
- What are the factors that could keep the U.S. from being successful?

The chapters that follow, we will include a review and analysis of the insights, challenges, and opportunities discussed from each of the four panels, then conclude with recommendations for DoD.

11 Dougherty, Chris. "CONFRONTING CHAOS: A NEW CONCEPT FOR INFORMATION ADVANTAGE." War on the Rocks. September 9, 2021. https://warontherocks.com/2021/09/confronting-chaos-a-new-concept-for-information-advantage/

12 Milley, General (Ret) Mark A. "Strategic Inflection Point: The Most Historically Significant and Fundamental Change in the Character of War Is Happening Now— While the Future Is Clouded in Mist and Uncertainty."

Joint All Domain Command and Control (JADC2)

In the classic "OODA" loop the first step is Observe, then Orient, Decide, and Act.[13] In anything more than very small unit operations, observe starts with sensing and communicating all known information about the battlespace. As warfighting concepts have evolved, complexity has expanded due to the interconnectedness of different sensors and the expanding range of operational control. Platforms need to be coordinated, especially in multi-Service all-domain operations against a near peer. Modern challenges require interoperability and interconnectivity, and this begins with effective and collaborative command and control. In a highly contested area, it is no longer acceptable or possible to operate successfully without working together efficiently.

JADC2 is a concept that is attempting to connect sensors from all the Armed Services (Army, Navy, Marine Corps, Air Force, and Space Force) as well as Defense and Intelligence Agencies (e.g., National Geospatial-Intelligence Agency, National Reconnaissance Office, and Defense Intelligence Agency) into a battle network. For the purposes of this paper, JADC2 is not just a concept, it is a capability that integrates networks, and it is also a non-programmatic system. It is a network, system, and capability. As enabling technologies have matured, sensors have become ubiquitous. There is a plethora of ground-based sensors, air & space-based sensors, and people; all platforms are now also sensors. Ground-based sensors include both traditional sensors and devices among the "internet of things." The number of potential sensors is exploding and continues to grow exponentially, projecting to grow at a compound annual growth rate (CAGR) of more than 20% for the internet of things, accelerometers, and so forth.[14]

During the NDIA panel, Retired Brigadier General Scott Stapp characterized JADC2 as pairing "the right sensor with the right shooter." The warfighter will soon be swimming in data. At a 20% CAGR, the amount of data available will double in less than 3.5 years. If future warfighting is dependent upon moving the data where it will be used – from command headquarters to fighting formations – JADC2 must be constructed to move the right data to the decision maker and then to the right shooter, not all data to every place. JADC2 is about moving data, anywhere, anytime. JADC2 intends to provide commanders with access to data, information, and intelligence from satellites, aircraft, ships, and ground-based radars to enable faster decision-making in war. JADC2 will make use of artificial intelligence (AI) algorithms to process the data collected from numerous sensors to identify targets, then recommend the optimal weapon – both kinetic and non-kinetic (e.g., cyber or electronic weapon) – to engage the target. To create greater interoperability between Services in support of joint operations, Lockheed Martin CEO, Jim Taiclet, is advocating the DoD establish a "JADC2 Standards Governance Body" convened by DoD with participation across a wide swath of defense and commercial industries.[15]

It must be acknowledged that all of the four strategic imperatives for Joint Warfighting are reliant on sense-make sense-act algorithms to include AI and Machine Learning (ML) tools. In a theater of war, the JADC2 concept's goal is to move and process data to enable simultaneous operations and integrated capabilities across all domains, including air, sea, land, space and cyber.

Traditionally, each Service developed independent battle management/command, control and communications (BM/C3) systems and networks, which were only compatible with those of other Services by happenstance. Typically, networks between the Services were not interoperable. For example, Army networks were unable to interface with Navy or Air Force networks. Some platforms and sensors developed by a Service are not even completely interoperable within that service.

DoD command and control (C2) can be best understood by breaking up the military domains: air, sea, land, space, and cyberspace. Historically, C2 is performed within these individual segments of the battlespace. This structure exists because traditional threats came from a single system, like aircraft or tank formations. In response, the military developed highly sophisticated (but costly) sensors to surveil the battlespace and provide information to a centralized command center (like an Air Operations Center or Army Command Post). Systems such as the E-3 Advanced Warning and Command System (AWACS) and the E-8 Joint Surveillance Target Attack Radar System (JSTARS) were optimized to provide situational awareness to commanders at these centralized outposts, where they could then direct military forces.

When the Allied force has an uncontested environment, cross-force communication and synchronization is not critical, and operations are optimized for a single (uncontested) function. These functions could be cross-Service, such as a ground force (Army) calling for close air support from the Air Force or Navy.[16]

During operations in Iraq and Afghanistan, any large-scale communications disconnect between the Services did not materially affect the lethality of the U.S. military given the adversary's inferior technological capabilities. As the world moves to "great powers competition", the inability to smoothly link all assets against a near-peer competitor will be a vulnerability. This vulnerability would be exacerbated in a potential conflict with China, as the U.S. would be operating with less time over vastly greater space with largely mobile assets, operating

13 Phillips, Mark. "Revisiting John Boyd and the OODA Loop in Our Time of Transformation." Defense Acquisition University, October 4, 2021. https://www.dau.edu/library/defense-atl/blog/revisiting-john-boyd.

14 Fact.MR. "Rising Deployment of 5G Is to Boost Internet of Things (IoT) Sensors Market by 20.3% CAGR by 2032." Accessed August 2, 2023. https://www.prnewswire.com/news-releases/rising-deployment-of-5g-is-to-boost-internet-of-things-iot-sensors-market-by-20-3-cagr-by-2032--301592304.html.

15 Lockheed Martin Corporation. "Statement: Jim Taiclet before the House Committee on Armed Services subcommittee on Cyber, Information Technologies, and Innovation on Industry Perspectives on Defense Innovation and Deterrence "September 20, 2023. https://www.lockheedmartin.com/en-us/news/statements-speeches/2023/hasc-statement---jim-taiclet.html.

16 Author, Al Shaffer, recalls deploying with the Army in the late 1980's with an embedded Air Force element that brought their own Air Force radios to communicate with air support assets. However, these air support assets could not communicate with the ground force–only the embedded Air Force element. This process was slow, but it worked when the U.S. and allies had dominant capabilities.

against an adversary with a mix of both mobile and fixed assets. The U.S. military and coalition partners are attempting to posture itself to compete with other great powers capable of challenging the U.S. in all domains. China has tailored their capabilities to counter the U.S. in the South China Sea area of operations. China (and Russia) have invested in anti-access/area denial (A2/AD) capabilities, including electronic warfare, cyber weapons, long-range missiles, and advanced air defenses.[17] These capabilities were developed to counter the traditional military advantages of the U.S. and allies, such as the ability to project power. By developing diverse A2/AD capabilities, competitors force the U.S. and allies to operate over a much wider geographic area, exacerbating the problem of command, control, and synchronization of friendly forces. This in turn increases the probability that friendly forces will not optimize – if not waste – available resources.

Thus, JADC2, if implemented correctly, will enable the DoD to mitigate future command and control challenges by converging across domains, environments, and functions in time and space. The envisioned end state is a DoD hybrid-cloud environment for the Joint Force to share information across communication networks and data links, thereby allowing different Services' sensors to connect to other weapons systems. Technological advances – such as an increased number of methods to engage a target, the proliferation of relatively low-cost sensors, and increased processing and analytical power to transform digital data into useful information – should enable the benefits of JADC2 to come to fruition.

JADC2 will provide commanders access to information and gives warfighters influence, control, and both physical and psychological advantages over the operational environment. The advantage may come from gaining greater awareness over a larger area, or with greater fidelity, or with fewer delays between sensing and updates. JADC2 will provide a better understanding of what is occurring in all domains that will drive friendly planning and execution. This shared situational awareness among the Services' systems produces a more lethal and effective military by allowing commanders to rapidly identify the target and choose the appropriate response.

NDIA ETI JADC2 Panel

During NDIA's panel on JADC2, the panelists described that the operator, at all echelons, needs to have access to information on all available assets in the region (domain). All ground, sea, air, space, and cyber assets must be linked. The vision of JADC2 is a joint force linked and integrated at all levels of command. The panel panelists illuminated the fundamental issue: "How do we design an architecture that is both endurable and flexible enough?" However, the problems extend beyond technical challenges.

Anthony Smith, Director of Command, Control, Communications and Infrastructure for DoD's Chief Information Officer, remarked, "A lot of the problems really go to the acquisition side of how we build our forces." While there are many joint strategy documents, Director Smith emphasized that – once the money starts flowing – the individual program is based on the Service's CONOPs, which are written towards communicating internally. Therein lies the need to "evolve our CONOPS" to fix "the front end of the acquisition cycle."

Ultimately, JADC2 will be a government-industry combined solution that allows each concept to move forward and pass information from one service to another. Drawing inspiration from the commercial sector is imperative to the success of JADC2, as industry has made great strides in networking and interoperability tools. Retired Brigadier General Richard "Scott" Stapp: Former Vice President of Capabilities and All Domain Integration, Former Chief Technology Officer, Northrop Grumman, reiterated that – at the end of the day – industry can build tools that allow for effective C2, but the Services need to decide how they want to control C2 assets that are tied together. General Stapp pointed out that "industry works across the services." Thus, industry is able to advance the JADC2 vision despite some of the barriers facing the Services such as the Program, Planning, Budget, and Execution (PPBE) process.

Dr. Michael Zatman, former Principal Director for Fully Networked Command, Control and Communications at the Office of the Under Secretary of Defense for Research and Engineering highlighted one of the biggest issues across departments as being synchronization. Historically, the Air Force's network has been the strongest. According to Dr. Zatman, "The Service networks are not all equal, and joint network is only as strong as the weakest component." During the panel, Dr. Zatman broke JADC2 into echelons:

1. Resilience in a highly contested environment
2. Interoperability between services across domains, which also includes between different classification domains
3. Interoperability with international partners
4. Interoperability between modern and legacy platforms

JADC2 Technology Enablers

In order for the promise of JADC2 to become a reality, the DoD will need to continue to mature several technologies and use specific acquisition strategies to treat JADC2 as an agile software development system that can adapt quickly. In some cases, the development will be more engineering than discovery, but the engineering will need to scale to the envisioned JADC2 end-state. This concept also calls for the consideration of a parallel digital acquisition system that can move much more quickly than the current acquisition system DoD has for major acquisition programs.

Modern Software Development Procedures: To be successful, JADC2 must be designed to incorporate rapid software updates, in days or less. Thus, successful implementation of JADC2 requires that deployed military and support personnel include dedicated coders (military or commercial) update the system. Success will also be heavily dependent having accredited pipelines beyond just coders as well as interfaces, which are the languages, codes, and messages that programs (e.g., Python, JavaScript, and PHP) use to communicate with each other and to the hardware.[18] Software will need to roll out in phases, with

17 A2/AD zones are composed of intelligence, surveillance, reconnaissance (ISR), and defensive and offensive strike systems. These systems include sensors; antiship, antiaircraft, and ground defenses; and long-range fires and are designed to prevent the U.S. from entering a close fight. The key strategic objective is not to defeat the U.S. in battle, but to increase the costs until the potential political gain is outweighed by the loss.

18 For more information on software acquisition, read the Hudson Institute's "Software Defines Tactics" report here: https://www.hudson.org/national-security-defense/software-defines-tactics-structuring-military-software-acquisitions.

ever increasing capabilities. The initial instantiation of JADC2 will likely just be a networked system with limited nodes. As the system grows, new sensors as well as data processing algorithms must be added.

Open Systems Architecture and Digital Engineering: While JADC2 is not exclusively a technology problem, there are technologies that must be developed or adopted to mature JADC2. JADC2 will not be static—that is to say, the architecture used to develop and implement JADC2 must be able to handle rapid technology updates. This implies that JADC2 will have to be designed in fully open system-compliant architectures with a digital backbone. While the DoD has issued guidance encouraging open systems and digital design, a complex system of systems like JADC2 must be constructed from the ground up. The intent is to allow virtually any company to "plug and play" their "app" into the open architecture and prevent vendor lock.

Artificial Intelligence (AI)/Machine Learning (ML): Since JADC2 is envisioned as a tool to assist decision making, AI/ML will be a critical enabler. JADC2 – to be effective – will need to access, process, and provide data in a data layer. These algorithms will be expected to complement the operator and fuse data for the "right" solution. While this could be done using data fusion, it would be more operationally useful to have data fusion with algorithms that can discern patterns and arrive at meaningful data analysis more rapidly. To be sure, JADC2 will not make the decision but it will enable the decision-maker to process mountains of data to support the commanders' decision-making processes. This will require a test environment that fuses real and synthetic data to provide a richer domain of potential scenarios. Finally, the Department will need to develop methods to evaluate the fitness of various AI/ML algorithms to understand what is operationally effective and suitable for fielding.

Human-Machine Teaming: The DoD will need to advance human-machine teaming to understand how data and information should be delivered to enable the *right* decision by the military decision maker, *at the right time, at the right echelons.* The goal is to create a system in which intelligence analysts interact with AI/machine learning (ML)-enabled machines to learn new insights from data. Human-machine teaming will directly tackle the challenge of analysts spending 80% of their time searching for data and 20% making sense of the data.[19]

Similarly, the employment of combinations of uncrewed and crewed systems will be a critical component of future operations. The high attrition rate of a peer conflict will stress the ability of the Services to replace both inventory and personnel. Improvements in computer processing, datalinks, software programming, and autonomy can enhance naval and air power by combining crewed and uncrewed systems to achieve mission objectives. Trust is a central element to the success of uncrewed and crewed teaming. Humans must be able to trust autonomous systems to conduct complex behaviors in changing environments. To explore uncrewed-crewed teaming, the Navy kicked off Integrated Battle Program 23.2 in August 2023, which focused on testing and evaluating medium and large unmanned surface vessels for integration into fleet operations.[20]

5G to Future G: 5G and more importantly "*Future*-G" wireless technology is a potential solution to reduce latency due to using satellite comms links. The 5G and *Future*-G solutions will be driven by commercial advancement, although the complete JADC2 solution will likely need to operate at the bands of the 5G/*Future*-G family of systems. The fusion of low, mid, and high band 5G will present an engineering challenge. Commercial advances in 5G offer high data capacity and low latency.[21] 5G also has advanced dynamic spectrum sharing, which allows multiple users to operate on the same frequency band as the electromagnetic spectrum becomes more congested. In fact, the Navy stated one of its primary JADC2 efforts focuses on removing proprietary network standards to enable interoperability with the other Services.[22] Another crucial consideration for Future G is governance. International standards for 5G were primarily set by China.[23] For Future G, the U.S. needs to encourage and resource the participation of U.S. and Allied personnel into the rulemaking process. However, American commercial standards may not fully translate to military utility; nevertheless, DoD can gain an advantage by leveraging the robust commercial research and development investments being made in radio frequency and signal processing by industry.

Fully Networked Command, Communication and Control (FNC3): FNC3 represents the "medium to long-term vision for JADC2," as it is focused on developing resilient and diversified communication paths for future battle networks.[24] FNC3 seeks to enable reliable communication across all of DoD's tactical and strategic assets – both modern and legacy systems. There are four critical tasks within FNC3 that need to be addressed:

1. Protected radio frequency (RF) Beyond-Line-Of-Site communications
2. Multi-user/multi-point high-data-rate laser communications
3. Communication with submerged assets
4. Communication with coalition partners[25]

---

19 U.S. Air Force, Department of Defense Fiscal Year (FY) 2021 Budget Estimates, Air Force, Justification Book Volume 3b of 3, Research, Development, Test & Evaluation, Air Force, Vol-III Part 2, February 10, 2020, at https://www.saffm.hq.af.mil/Portals/84/documents/FY21/RDTE_/ FY21%20Air%20Force%20Research%20Development%20Test%20and%20Evaluation%20Vol%20IIIb%20- %20updated.pdf?ver=2020-02-12-125427-660.

20 U.S. 7th Fleet Public Affairs, "Unmanned Surface Vessel Division Arrives in Sydney." U.S. Pacific Fleet. Department of Defense. October 25, 2023. https://www.cpf.navy.mil/Newsroom/News/Article/3569198/unmanned-surface-vessel-division-arrives-in-sydney/#:~:text=All%20five%20U.S.%20Navy%20vessels,operations%20alongside%20manned%20surface%20combatants.

21 CRS Report R45485, Fifth-Generation (5G) Telecommunications Technologies: Issues for Congress, by Jill C. Gallagher and Michael E. DeVine.

22 Ibid.

23 Bruer, Alexandra, and Doug Brake. "Mapping the International 5G Standards Landscape and How It Impacts U.S. Strategy and Policy." Information Technology & Innovation Foundation, November 2021. https://www2.itif.org/2021-5g-standards.pdf.

24 Harrison, Todd. "Battle Networks and the Future Force," August 5, 2021. https://www.csis.org/analysis/battle-networks-and-future-force.

25 OSD (R&E) Communications & Networking Infrastructure (C&NI) Broad Agency Announcement (BAA). "SAM.Gov." The Office of the Secretary of Defense Director of Defense Research & Engineering for Advanced Capabilities (DDR&E (AC)) Communications & Networking Infrastructure (C&NI) March 2020. https://sam.gov/opp/3d2512d1609847e9888359bf8ad05175/view

JADC2 Cultural Acceptance and Barriers

To reach the interoperability goals set by the Joint Warfighting Concept, the Services must overcome deep cultural barriers. Each Service has its own instantiation of JADC2. The Air Force is developing the Advanced Battle Management Systems (ABMS), the Navy has Project Overmatch, and the Army has Project Convergence. All are largely being developed independently. There is no unifying concept of operations (CONOPS) or set of standards for JADC2. General Scott Stapp noted, "The Services [historically] tended to hunt like bears. They were territorial. They operated in their territory, and they did it alone." For JADC2 to work, "They need to operate like a wolf pack, and they need to hunt together."

Budget and requirements processes tend to be biased against joint capabilities, such as those envisioned under JADC2. While there are joint strategy documents that address operating with international forces, the funds that go into a Service's weapons program are based on that Service's mandates to organize, train, and equip their forces. This process inherently creates acquisition challenges given that a Service's CONOPS is written towards internal BMC3. Since the Services have a historical preference for buying next-generation platforms rather than the sensors, payloads, and communications systems needed to make both existing and next-generation platforms work together more effectively, there is a systemic disconnect, as hardware upgrades can take up to five years and more to implement. To drive acquisition of JADC2 capabilities, CONOPS must reflect an effort to synchronize resources to ensure that the Services' radios, antennas, and satellites are interoperable.

There are a few additional factors that could keep the U.S. from success in fully realizing the vision of JADC2. First, competitor electronic warfare (EW) capabilities could prevent or degrade the U.S. from being able to communicate. China is going to great lengths to upgrade the People's Liberation Army (PLA)'s defensive and offensive EW capabilities. In fact, China fields significant communications and signals intelligence (SIGINT) systems throughout the South China Sea and is expected to continue investing in EW.[26] As such, the proliferation of jammers requires electronic resilience, or anti-jamming properties, to maintain communication resiliency.

Second, the U.S. is not adept at integrating multilevel security systems. Data that does not flow out at an accessible level inhibits most warfighters from being able to actually use the information. Furthermore, the inclusion of allies and partners increases security and data sharing challenges. Whatever solution DoD chooses to adopt will need to be adopted by allies. Relationships are central to future conflict. Appropriate, relevant operational and intelligence data must be accessible to U.S. and allied warfighters at all security classification levels.

Lastly, disinformation or misinformation can prevent commanders from accurately adapting to the changing battlespace. Data is integral to helping commanders make faster decisions and better integrate actions across domains. False information would lead to decision-support tools feeding commanders inaccurate or incomplete information. Therefore, it is imperative that the Services determine how to best protect networks from false information. Similarly, AI systems must also be trained on data sets that are free of false information.

Summary

Achieving the promise of JADC2 will require several high technology areas to be simultaneously developed, and JADC2 will, as a primarily software enabled capability, be rolled out in increments. Synchronization has always been a challenge across DoD. JADC2 will require a robust development program to create the necessary decision aid tools, but progress is being made, and the future of U.S. and allied combat capabilities will depend upon it. A century ago, success on the battlefield was largely the outcome of dominant materiel and personnel. As the world progresses from the mechanical to the information era, future battles will be won by the speed and accuracy of decision-making. In almost any information age warfare scenario, the faster a side can gather, process, disseminate, and act on information, the greater the probability of battlefield success. JADC2 is the Department's highest profile approach to provide this capability. Its vision is not easy to realize and will require a comprehensive architecture to move the data from the right sensor to the right combatant, but the DoD is moving in the right direction.

26 Funaiole, Matthew P., Joseph S. Bermudez Jr, and Brian Hart. "China Is Ramping Up Its Electronic Warfare and Communications Capabilities near the South China Sea," December 17, 2021. https://www.csis.org/analysis/china-ramping-its-electronic-warfare-and-communications-capabilities-near-south-china-sea.

Joint Fires

Joint Fires is defined *as fires produced during the employment of forces from two or more components in coordinated action toward a common objective.*[27] Simply, it envisions integrating theater-wide fires to create maximum effects without wasting munitions. Joint Fires leverage joint, interagency, intergovernmental, and multinational capabilities at decisive points in time and space to achieve common objectives.[28] Coordination of the movement and command and control of shooters from different Services is exceedingly difficult, but the potential benefits of effective Joint Fires becomes an essential element of deterrence. Joint Fires is not a new term; in fact, it was defined in a Joint Publication as early as 2010; but today, a new dimension to Joint Fires is being added and exercised: "Integrated" Joint Fires. The term "integrated" is crucial in advancing fires potentially launched across all domains and across multiple services.

There are an enormous number of "potential targets" in a potential invasion of Taiwan by the PRC. According to the 2023 DoD China Military Power Report (CMPR), the Chinese force includes:

- Roughly 2.2 million active members, with growth in Naval and Air Forces, and a continued steady decrease in the PLA Army
- 147 Surface Combatant ships (50 Corvettes, 47 Frigates, 42 Destroyers, and 8 Cruisers) and two domestically built aircraft carriers, the first operational in 2019 and the second in 2024
- Over 50 submarines (47 Attack, 6 Nuclear-Powered Attack, and 6 Nuclear-Powered Ballistic Missile)
- Over 1,900 fighter aircraft (more than 1300 of 1900 total fighters are fourth generation), and the fifth generation J-20 stealth fighter has recently become operational
- 500 bombers equipped with long range cruise missiles
- Over 1,250 land based mobile missile launchers[29]

Fires are not limited to just strikes against fielded enemy units, but they also encompass targets such as enemy leadership, infrastructure (e.g., transportation, energy, and C2), and war-making industries. Moreover, it is quite publicized that the U.S. has a significant shortage in munitions. Unfortunately, this shortage has been made worse by decades of neglect of the munitions industrial base leaving little surge capacity.[30] The problem has been exacerbated by the use of U.S. and allied munitions in Ukraine. An important consideration for Joint Fires is the need to optimize the efficiency of kinetic strikes, and not launch munitions at targets that have already been neutralized. This becomes challenging considering many U.S. fires are covering longer distances. For instance, the Army is currently in low-rate initial production and fielding the Precision Strike Missile (PrSM), with a range of up to 300 miles.[31] The Air Force had its initial launch of the 500 mile plus AGM-183 Air-Launched Rapid Response Weapon (ARRW) in Dec 2022.[32] The Navy has the 1,000 mile Tomahawk, and the 200 mile plus Long Range Air to Surface Missile (LRASM).[33] These munitions all fly at different speeds, from different platforms, and use different command and control systems. Coordinating the strikes becomes a complex problem.

In a future great power war, the cost – in terms of equipment and casualties – will be very high. Therefore, the best way forward would be to ensure there is credible deterrence. Credible deterrence includes the capability to strike a series of valuable adversary targets quickly and accurately. Deterrence occurs when the potential adversary recognizes the damage the U.S. and partners could inflict in a conflict. It also means revealing more about potential capabilities.

NDIA ETI Joint Fires Panel

While the joint force understands what is conceptually considered fires and how to apply traditional fires, the targeting cycle is systematically stovepiped. All four panelists during the NDIA ETI panel noted the cultural challenge of Joint Fires. Historically, the Services prefer using sensors that they have practiced with. The NDIA ETI panelists identified the need to implement Joint Fires during exercises or simulators practicing employing different shooters working at different speeds simultaneously arriving at the same target. Synchronization is of extreme importance for successful joint fire operations, requiring the integration of the simultaneous activities of intelligence, air operations, ground operations, maritime operations, and logistics in time and space.[34]

Another major change over time that was highlighted during the NDIA ETI panel is the complexity of fires planned and coordinated between all Services (to include Space Force) as weapon ranges increase. The Army has fast tracked the 500-km plus "Precision Strike Missile" for early operational capability in 2023. Three Services are developing hypersonic capability with the Army's Long Range Hypersonic Weapon set to be operational in late 2023.[35] The Navy began fielding the Long-Range Anti-Ship Missile in 2018, a missile

27 Joint Chiefs of Staff. "Joint Fire Support." Department of Defense. Joint Publication 3-09. 10 April 2019. https://www.jcs.mil/Portals/36/Documents/Doctrine/pubs/jp3_09.pdf
28 Ibid.
29 "Military and Security Developments Involving the People's Republic of China." Annual Report to Congress. U.S. Department of Defense, 2023. https://media.defense.gov/2023/Oct/19/2003323409/-1/-1/1/2023-MILITARY-AND-SECURITY-DEVELOPMENTS-INVOLVING-THE-PEOPLES-REPUBLIC-OF-CHINA.PDF.
30 Goure, Dan. "Pink Flamingo: The U.S. Military Will Pay for Its Munition Shortage." The National Interest. 10 November, 2022. https://nationalinterest.org/feature/pink-flamingo-us-military-will-pay-its-munition-shortage-205777
31 Judson, Jen. "Army Weighs Options on Extending Range of Precision Strike Missile." Defense News, October 13, 2022. https://www.defensenews.com/digital-show-dailies/ausa/2022/10/13/army-weighs-options-on-extending-range-of-precision-strike-missile/.
32 Insinna, Valerie. "Air Force Successfully Tests First Fully-Operational Air-Launched Hypersonic Missile." *Breaking Defense*, December 12, 2022. https://breakingdefense.sites.breakingmedia.com/2022/12/air-force-successfully-tests-first-fully-operational-air-launched-hypersonic-missile/.
33 Friedberg, Sydney. "LRASM vs Tomahawk, Raytheon gets $119M for Anti-Ship Missile." Breaking Defense. Sept 2017. https://breakingdefense.com/2017/09/tomahawk-vs-lrasm-raytheon-gets-119m-for-anti-ship-missile/#:~:text=A%20prototype%20Maritime%20Strike%20Tomahawk,the%20company's%20Tomahawk%20missile%20factory.
34 Sevalia, Roy C., and David C. Sims, "Fighting Deep with Joint Fires," Air and Space Power Journal, Vol. 14, No. 1, 2000. https://www.airuniversity.af.edu/Portals/10/ASPJ/journals/Chronicles/sevalia.pdf
35 Perez, Zamone. "First Unit Fielding Army Hypersonic Missile in 2023." Army Times, January 1, 2023. https://www.armytimes.com/news/your-army/2023/01/01/first-unit-fielding-army-hypersonic-missile-in-2023/.

with estimated range in the 200-300 nm category. The FY2022 budget request from the Department of Defense increased the production of Tomahawk missiles. The complexity of a simultaneous strike from multiple locations with projectiles at different speeds and range becomes a tough command and control problem. When he was unveiling the Joint Fires Directive, General John Hyten said,

> ***The idea of Joint Fires is both a huge challenge and somewhat controversial.***

Noting that he'd been criticized for saying this, Hyten explained that

> ***In the Joint Warfighting Concept, fires come from all domains and all Services, no restrictions. Why? Because when the fires come from all domains and all Services with no restrictions, the adversary can't figure out where they're coming from, and they have no way to defend themselves against them. Now, that's, that's a purely aspirational requirement, but I hope everybody can see that if you can do that, you would change the equation on any future battlefield.***

Lastly, the NDIA ETI panelists pointed out another additional aspect to the evolution of capabilities that complicates the calculus for Joint Fires: mobility. The need for mobile shooters was best articulated by former Vice Chairman of the Joint Chiefs of Staff, Admiral Sandy Winnefeld. According to the Proceedings of the U.S. Naval Institute, Admiral Winnefeld said, "Sensor capability and weapons lethality have evolved to the point that, where finders have the advantage over hiders, one really does not want to be a hider. Unfortunately, that is where a good bit—though not all—of our stuff operates."[36] Admiral Winnefeld is referring to the fact that it is almost impossible to hide a non-mobile shooter (perhaps except for submarines), so that in Joint Fires, the friendly shooter should come from a mobile platform.

Joint Fires Technology Enablers

Joint Command, Control and Communications: While JADC2 is a strategic imperative itself, it also is a fundamental enabler of Joint Fires; JADC2 is both a battle network and a capability for coordination. Once the weapon–target pairing has been made, it is essential to coordinate this information to any and all shooters via secure communication links. In missions where a missile has a primary and secondary target, reliable communication throughout the operation is often essential. According to AFCEA, U.S. Indo-Pacific Command officials expect that the initial protype of the Joint Fires Network (JFN) will be ready in December 2023, and will begin experimenting with a second iteration prototype in the summer of 2024 during the Valiant Shield exercise.[37] The JFN is Indo-Pacific Command's push towards JADC2; it is expected to include a decentralized architecture, automation of fire control functions and a common operating picture across the joint force for asset management.

Jam-resistant terminal seekers and enroute communications: While great power competition has implications for nearly all aspects of warfare, operating in a contested electromagnetic environment entails many unique complexities. The West must maintain some degree of contact during ingress of the weapon and has to be able to acquire and stay locked on a target at terminal end game. With longer range weapons against moving targets, the need for resilient beyond-line-of-sight connectivity between the weapon and the sensor providing the targeting updates becomes even more crucial.

Timely target acquisition and communications to a planning cell: One reality of a locally deployed adversary is the preponderance of mobile shooters. That means adversary equipment may only be targetable for a short period of time. The U.S. needs to have sufficient overhead aerial and space (and potentially ground-based and undersea) platforms and sensor capacity to

1. Determine when the target comes out from hiding
2. Pass the target to a targeting cell
3. Launch in only a few minutes. Moving quickly will require exquisite information that can be passed quickly to assist decision aids

Automated Planning Tools using Artificial Intelligence: There are many challenges in coordinating Joint Fires, however there were two problems that received more attention during NDIA's panel. First, given all available munitions in a theater of operations, how does one prioritize the targets and then pair the target with the best munition(s) to maximize the probability of success while not expending multiple rounds on the same target? Said another way, what is the optimal path to get assured kills while maintaining as much theater capacity as possible? The second challenge is coordinating complex multitarget strikes with munitions that travel at different speeds and over different distances. The NDIA ETI panelists emphasized the need

36 Winnefeld, Admiral James A (Ret). "Break out or Fail." Proceedings of the US Naval Institute. April 2017. https://www.usni.org/magazines/proceedings/2017/april/break-out-or-fail

37 Seffers, George I. "Initial Joint Fires Network To Be Ready Next Summer." AFCEA. November 9, 2023. https://www.afcea.org/signal-media/initial-joint-fires-network-be-ready-next-month

for specialized algorithms to optimize the fires. Dynamic algorithms will help commanders plan and execute the mission.

Near Real Time Battle Damage Assessment from Range: Since it is true that the U.S. and its allies do not have unlimited munitions, and most Joint Fires will be indirect (beyond line of sight), it is critical to have real-time battle damage assessments. When strikes are shorter range, this is not difficult. When the targets are several hundred miles away, it is essential to have a sensor that can safely gather all necessary information. This would likely be either a satellite or UAS mission. If space, the reality is that this would likely be a proliferated LEO mission. This is a mission enabled by JADC2.

Manufacturing: It is clear the U.S. and allies have a shortage of critical munitions. There is also a lack of industrial capacity to quickly refill the stockpile. While this is a serious issue, there are steps that can be taken to limit potential vulnerabilities. Above all else, demand signal is the most significant determinant of the health and resilience of the U.S. manufacturing industry. Oftentimes, industry is eager to make internal investments to their manufacturing capabilities but will only make those investments if there is a high probability of returning a profit. By dedicating funds to the transformation of existing plants into modern manufacturing facilities, processes will become more automated and efficient leading, in theory, to greater capacity.

As munitions increase in range, so do procurement costs. In ETI's Hypersonics Supply Chain Report, the "Boost Glide" hypersonic weapon is estimated to cost about $100M per missile.[38] There are similar costs expected for the previously mentioned Air Force's ARRW. The exact cost of the Air Force Hypersonic Attack Cruise Missile is unknown, but the best estimates are $5-$10M per unit. However, hypersonic supply chains are fairly nascent; specialty materials are not widely available and hypersonics are not produced at scale, which drives the unit cost up. ETI notes that "system affordability is not quantifiable per se, since it depends on a complex set of prioritization decisions within the Pentagon, White House, Congress, and industry."[39] Even the low slow Tomahawk costs about $2M per missile and LRASM about $3.5M each.[40] The Army PRsM will cost roughly $1.5M in initial low-rate production in FY22.[41] In order to achieve any type of realistic magazine depth, these costs will need to come down, and the DoD will need to think about economies of scale or ask for multi-year authority.

Summary

Like JADC2, Integrated Joint Fires is both a technological and cultural challenge. Coordinating fires from multiple locations with multiple munitions is a significant logistical and operational undertaking. Joint Fires expands to a problem of communicating the Joint Fires plan, optimizing fires against the targets, standoff Intelligence, Surveillance and Reconnaissance (ISR) for battle damage assessment, and redirecting follow-on fires. Using just enough munitions to obtain a kill is a cultural issue—it is not uncommon to employ a doctrine of "shoot, shoot, shoot, look" against a specific target. This expends munitions at a higher rate than is necessary. With limited inventory and industrial capacity, the U.S. must consider what the right munitions are in the mid- to long-term and how to effectively employ them in ways that allow it to achieve its objectives in an efficient manner. Thus, finding new methods through new technologies can help preserve and maximize munitions, thereby extending the combat capabilities of U.S. and allied forces.

38 Wostenberg, Rebecca, et al. "Hypersonics Supply Chains: Securing The Path To The Future." Emerging Technologies Institute. May 2023. https://www.emergingtechnologiesinstitute.org/-/media/ndia-eti/reports/hypersonics/hypersonics-supply-chain-reportfinal2.pdf?download=1.

39 Ibid.

40 Cohn, Jacob, Timothy Walton, Adam Lemon, and Toshi Yoshihara. "Leveling The Playing Field Reintroducing U.S. Theater-Range Missiles in a Post-INF World." Center for Strategic and Budgetary Assessments, 2019. https://csbaonline.org/uploads/documents/Leveling_the_Playing_Field_web_Final_1.pdf .

41 Judson, Jen. "US Army to fund Extended Range Precision Strike Missile in FY22." Defense News. June 14, 2021. https://www.defensenews.com/land/2021/06/14/us-army-to-fund-extended-range-precision-strike-missile-starting-in-fy22/

Contested Logistics

The U.S. may no longer have the advantage of uncontested logistics or air supremacy in future conflicts. In modern warfare, it will be almost impossible to hide logistics bases and capabilities. This is especially true in any form of competition with China, which has a very dense network of sensors and ground-based radars to find and fix U.S. and Allied logistics facilities. In a South China Sea scenario, the U.S. and allies will need to operate their logistics bases within the range of Chinese ballistic, cruise missiles, and bombers.

It is also important to acknowledge that with the FY2024 President's Budget submission, DoD requested $9.1 billion in funding for the Pacific Deterrence Initiative (PDI).[42] This included a request for a $1.1 billion investment in improved logistics, maintenance capabilities, and prepositioning of equipment, munitions, fuel, and materiel in the pacific. There is also $2.1 billion for infrastructure improvements to enhance the responsiveness and resiliency of U.S. forces as well as an additional $2.9 billion for a modernized and strengthened presence.

For nearly three decades, the U.S. military has conducted uncontested and generally predictable deployments from home stations to operational theaters because adversaries lacked the capability to significantly affect deploying U.S. and allied units at home station or while in transit to a theater of operations.

In a competitive world, the U.S. will no longer have the luxury to "move mountains." Now, U.S. competitors may use modern capabilities to reveal U.S. troop movements, disrupt or delay them when deploying forces on the battlefield, and attack units in transit. A conflict with the PRC would require significant levels of maritime logistics support. The People's Liberation Army Navy (PLAN) boasts the largest naval fleet in the world with an inventory of 370 ships and submarines, including more than 140 major subsurface combatants – with a large portion of ships built in the last decade.[43] The Chinese Air Force has modernized, shifting from a defensive force to one that projects power beyond the Chinese Mainland.[44] Considering these developments, Contested Logistics is focused on creating new ways to deliver fuel, munitions, and supplies within the weapons engagement zone.

Contested Logistics consists of allies, partners, and industry working together to ensure that the military Services have the capabilities they need regardless of direct targeting of logistics. More than 90% of the military cargo needed by U.S. forces is transported by sea and the movement of military cargos in volume by ship is likely to remain the most efficient and cost-effective method of transportation for the foreseeable future.[45] Potential targets include logistics operations, munitions depots, and transiting vessels to and from the warzone. The goal is to have multiple locations to sustain the force, avoiding centrally locating supplies. As laid out by the Joint Concept for Contested Logistics, the U.S. proposes three lines of effort to meet this goal:

1. Resilient, integrated logistics command and control
2. Assured joint power projection
3. Sustainment for distributed operations[46]

The most valuable enabler for logistics capabilities that overcome the challenges of Contested Logistics is the relationships the U.S. shares with its allies and partners. For example, AUKUS is a trilateral security pact between the U.S., Australia, and the U.K, which could enhance logistics and sustainment capabilities of surface and subsurface vessels in the Indo-Pacific. The Philippines just announced that it will speed up implementation of a defense agreement that allows U.S. troops to rotate for extended periods and access local military bases.[47] While these agreements indicate positive working relationships, it is important that there are tangible outcomes. In fact, access to allied bases and airspace during the critical first few days of deployment can be more important than allied platforms and weapons contributions.[48] The U.S. may not be successful if the forward bases DoD has access to are insufficient. This could mean that bases are not secure enough to be a distribution point, or communications are not assured in a contested electromagnetic environment. Insufficient infrastructure could also look like a lack of sheltered aircraft or hardened fuel supply points. There are only a limited number of places in the Indo-Pacific that the U.S. and allies can use to build capacity and capability. If partner capabilities are not improved to augment U.S. munitions stockpiles, deterrence weakens, and the U.S. loses out on additional supply chain diversification.

By focusing on developing capabilities to overcome the challenges of Contested Logistics, the DoD is building resiliency and flexibility into operational and regional plans. The U.S. achieves resilient logistics by leveraging important relationships with commercial companies, allies, and partners. Bringing in commercial partners gives DoD access to basing, storage, or relationships with ports that it would not otherwise have. The DoD can also leverage partners and allies through basing agreements, allowing the Services to deploy installations, troops, or other assets. Partners and allies can also be used for production and airlift capabilities. The investments DoD makes will ensure it has prepositioned forward munitions, partner and allied support, and distributed logistics that are sustainable while under persistent multi-domain attacks.

---

42 Department of Defense. "Pacific Deterrence Initiative." March 2024. https://comptroller.defense.gov/Portals/45/Documents/defbudget/FY2024/FY2024_Pacific_Deterrence_Initiative.pdf.

43 Military and Security Developments Involving the People's Republic of China." Department of Defense. 2023

44 "The Dragon's Wing: The People's Liberation Army Air Force's Strategy > Air University (AU) > Journal of Indo-Pacific Affairs Article Display." Accessed August 2, 2023. https://www.airuniversity.af.edu/JIPA/Display/Article/3111108/the-dragons-wing-the-peoples-liberation-army-air-forces-strategy/.

45 Walton, Timothy, Harrison Schramm, and Ryan Boone. "Sustaining the Fight: Resilient Maritime Logistics for a New Era." Center for Strategic and Budgetary Assessments, April 23, 2019. https://csbaonline.org/research/publications/sustaining-the-fight-resilient-maritime-logistics-for-a-new-era/publication/1 .

46 Joint Chiefs of Staff. "Joint Concept for Logistics." Department of Defense. September 25, 2015. https://www.jcs.mil/Portals/36/Documents/Doctrine/concepts/joint_concept_logistics.pdf?ver=2017-12-28-162028-713

47 Venzon, Cliff. "Philippines to Accelerate U.S. Defense Deal on Base Access." Nikkei Asia. August 2, 2023. https://asia.nikkei.com/Politics/International-relations/Philippines-to-accelerate-U.S.-defense-deal-on-base-access.

48 Myron, Hura, et al., Interoperability: A Continuing Challenge in Coalition Air Operations, RAND Corporation at 170-172 (2000)

NDIA ETI Contested Logistics Panel

During the panel on Contested Logistics, the central focus was on how to build flexibility in logistics, plans, and operations to ensure – during war – the warfighter is sufficiently equipped. Ms. Kristina O'Brien, former Principal Deputy Director for Logistics on the Joint Staff, set the stage for the workshop by framing how the Joint Staff thinks about a contested environment. Beyond adversarial capabilities, other factors include delays at ports – such as the 2021 Suez Canal obstruction[49] – or even weather. From a Joint Staff perspective, the Joint Requirements Oversight Council (JROC) is one method for building resilience into logistics plans and assessing joint military capabilities. Ms. O'Brien also emphasized the role of private companies: "... it's very important as we think about operating in this contested environment and building resiliency to make sure that we leverage the capabilities that our commercial partners have."

Mr. Steve Morani, Principal Deputy Assistant Secretary of Defense for Sustainment in the Office of the Undersecretary of Defense for Acquisition and Sustainment, shared his thoughts on DoD's approach to sustainment. Notably, sustainment was "codified" in the 2022 National Defense Strategy, which is unprecedented. This drove sustainment reforms in DoD in two areas. First, DoD would articulate how it "will prioritize and integrate sustainment of major defense acquisition programs, core logistics capabilities, and commercial logistics capabilities." Second, it led to DoD to consider a framework for "addressing contested logistics, including investments in related infrastructure, authorities, force posture, and in emerging technologies such as advanced computing." The key point is to identify service and DoD-wide priorities and align resources in the POM. This enables DOD to have specific objectives, including providing concrete sustainment solutions to the Services and provide support to both the defense and organic industrial base.

Mr. Terrence Emmert, Acting Assistant Secretary of Defense for Mission Capabilities in the Office of the Under Secretary of Defense for Research and Engineering (R&E), focused on how critical relationships are for technology to support the Contested Logistics mission. To avoid what Mr. Emmert called "stranded technology", R&E has decreased the distance between engineers and the warfighting community. This is to help align resources with the gaps identified during the requirements process, ensuring that technology turns into a viable capability for the warfighter. Given the importance of experiments, wargames, and table-top exercises to defense planning scenarios, Mr. Emmert emphasized the significance of bringing engineers into the "actual scenarios" in which those technologies will be used in. Other key relationships are with the acquisition community and international partners – all of whom will contribute to the ability of DoD to respond in a contested environment using new technologies.

A core element of the panel was defining and thinking through global visibility in a pacific theater. Data is foundational to many of the solutions. Brigadier General Gavin Garner, U.S. Indo-Pacific Command Director of Logistics, began his introductory remarks with "We do not see data collectively as a joint force." While BG Garner noted the Services are "getting better with things like fuel," data is still funneled through stovepipes. BG Garner gave two goals for global visibility:

1. Understanding U.S. logistics supply chains – "what we have, where it is, and how we're going to move it from A to B"
2. Understanding "red logistics," referring to adversary supply chains

All of these considerations are driven by data. BG Garner ended on a positive note, stating there are several initiatives on the Joint Staff Logistics Capability Board to understand how the Military Services are gathering data and find ways to make it interoperable.

Contested Logistics Technology Enablers

Gen. Minihan, Commander of Air Mobility Command, recently stated that improving the connectivity between mobility air and ground crews is the best investment the Air Force can make for preparing to operate across the Pacific.[50] There is a great need for automated tools to train planners to react to surprises—for example, what to do if a logistics node goes down due to weather, attack, or some other factor. Gen Minihan also recently outlined three areas for improvement, which came out of Air Mobility Command's Mobility Guardian 2023 exercise:

1. Strengthen command relationships to prevent wasteful efforts during operations
2. Enhance command and control by investing in beyond-line-of-sight communications
3. Improve Airmens' ability to quickly serve the joint force in an unfamiliar environment[51]

JADC2 or some other assured communication network: Logistics – contested or otherwise – relies on a common understanding of where all goods and supplies are located. This means the information supporting these Contested Logistics operations needs to be continuously shared and updated, as envisioned under JADC2. Thus, the successful development of the JADC2 vision will enable Contested Logistics operations.

Decision Aids to Optimize Transportation Plans: During the panel, participants explained the balance of needing to transport the "right" amount of fuel, food, replacement parts, and munitions to the logistics node without sending "too much" equipment. When every movement risks human life, the DoD wants to minimize the exposure. The question is, "How much is enough, and how does one move the equipment most efficiently?" The Department needs to build a

49 In March 2021, the Suez Canal was blocked for six days by the ***Ever Given***, a container ship that ran aground due to strong winds from a sandstorm. Ms. Kristina O'Brien admitted DoD had critical supplies on the *Ever Given*.

50 Roza, David. "Minihan: Connectivity is the 'Single Best Investment' For a Better Mobility Fleet." Air and Space Forces Magazine, September 10, 2023. https://www.airandspaceforces.com/air-force-minihan-mobility-connectivity/

51 Roza, David. "After Mobility Guardian, Minihan's Advice For His Troops: 'Be Demanding of Me'." Air and Space Forces Magazine, September 10, 2023. https://www.airandspaceforces.com/minihan-mobility-guardian-lessons/#:~:text=Class%20Caleb%20Parker.-,After%20Mobility%20Guardian%2C%20Minihan%E2%80%99s%20Advice%20For%20His,%3A%20%E2%80%99Be%20Demanding%20of%20Me%E2%80%99&text=In%20July%2C%20Air%20Mobility%20Command,the%20Pacific%20for%20two%2E2%80%99weeks

multi-dimensional system to dynamically plan for Contested Logistics using data which can then be used to optimize the system using advanced data analytics, including artificial intelligence algorithms.

This logistics flow relies on data. Data is the most influential underlying enabler of successful Contested Logistics operations. Both logistics intelligence and joint force logistics capabilities are driven by data. Currently, DoD lacks sufficient visibility into the commercial supply chains that support its programs. The DoD needs to be able to see the end-to-end supply chain and strengthen it when possible. Similarly, this insight also applies to the joint force, which is culturally apprehensive about making data accessible across Service and organizational boundaries. Data transparency between the Services is an uncomfortable, but necessary step in building solutions for the operational challenges of Contested Logistics. It is inherently difficult for the Services to give another entity information. Information sharing is a technical problem, but primarily a matter of trust for fear of the services encroaching on each other's missions. Data-sharing is essential to developing AI tools that help with data management, or specifically the diversification of logistics support across the Pacific Ocean.

Unmanned Systems: Given the cyber and kinetic capabilities that the PRC possesses, unmanned systems will play a vital role in delivering supplies to troops within the adversary's weapons engagement zone. The use of inexpensive platforms allows DoD to plan for a war of attrition, in which the loss of material (e.g., unmanned vessels or aircraft) does not inhibit resupply. The joint force should be able to sustain operations by air, land, or sea in a contested environment. The Services are experimenting with a number of unmanned platforms to support logistics missions. For example, in March 2023, the Marine Corps Combat Development and Integration demonstrated the Tactical Resupply Unmanned Aircraft System (TRUAS), which is a highly automated drone-like aircraft capable of carrying a 150-pound payload and only requires two Marines to operate.[52] The future combat environment provides a rich opportunity for unmanned systems – like the TRUAS – to be employed to deliver cargo without the threat of losing personnel.

Electronic Warfare (Offensive and Defensive): In summer 2023, U.S. Strategic Command officially established the Joint Electromagnetic Spectrum Operations Center (JEC) in recognition of the increasingly contested electromagnetic operating environment.[53] All Contested Logistics operations requires asset visibility in time and space. This is a multi-dimensional problem where commanders are trying to continuously determine: asset location, quantity, speed, and direction of movement. This information will have to be shared continuously throughout the battlespace. Overcoming the challenges of Contested Logistics will require enhanced anti-jam capabilities as well as communications modes that maximize throughput in all frequencies, as there will be a need to hide information by rapidly altering frequency and waveforms used to transmit the data.

Additive Manufacturing: Additive manufacturing (AM) could support efforts to ensure that the munitions, components, and materials needed by the Services are available to forces operating in the Indo-Pacific, where the U.S. is limited by the "tyranny of distance." A major objectives within the Contested Logistics mission set is to secure multiple options of meeting the logistical demand once the battlespace is contested and sensors are degraded. For example, AM provides another option for creating next generation munitions by increasing the production performance and lowering costs.[54] AM can also support maintenance needs while deployed; this led U.S. Naval Sea Systems Command to install an AM printer on the Virginia-class submarine USS New Hampshire.[55] As DoD determines which specific solutions AM can provide, the goal should be a production capability that allows the Services to replace parts rapidly and reliably.

Rapidly Deployable Hardened Air Shelters (HAS): In the wargames hosted by CSIS mentioned above, up to 90% of the combat aircraft were destroyed on the ground.[56] During a panel discussion, Lt. General (Retired) Dave Deptula cited HAS as one of his highest needs, yet the U.S. has not fortified its forward bases. From a technology perspective, the DoD needs to develop new designs for HAS that can be quickly assembled, yet strong enough to withstand attacks. This could include the establishment of new directed energy weapons to protect against rockets, mortars, artillery, drones, and cruise missiles. Other potential innovations could include rapid runway creation or repair to allow supply or other aircraft to quickly use runways after attack.

Summary

The U.S. and allies can no longer assume they will be able to operate freely in the battlespace with uncontested logistical superiority. In fact, the U.S., with its allies and partners, will face substantial difficulties in any South China Sea and/or Taiwan Strait operation. Supplies, food, fuel, and parts will need to be moved over very long distances, likely within the weapons engagement zone of an adversary. This type of operation requires greater planning and enhanced capabilities in everything from hardened facilities to operating in a contested electromagnetic spectrum. Without developing the concepts, doctrine, and technical tools to operate in this type of condition, the U.S. and Allied forces could face defeat.

52 DVIDS. "Quantico Hosts a Successful Tactical Resupply Unmanned Aircraft System Demonstration." Accessed August 2, 2023. https://www.dvidshub.net/news/442269/quantico-hosts-successful-tactical-resupply-unmanned-aircraft-system-demonstration.

53 U.S. Strategic Command Public Affairs. "U.S. Strategic Command Stands Up Joint EMS Operations Center." July 26, 2023. https://www.afgsc.af.mil/News/Article-Display/Article/3471964/us-strategic-command-stands-up-joint-ems-operations-center/

54 Department of the Army. "Additive Manufacturing to Provide Soldiers with Cutting-Edge Munitions." August 2, 2023. https://www.army.mil/article/233054/additive_manufacturing_to_provide_soldiers_with_cutting_edge_munitions.

55 Sharma, Soumya. "US Navy Submarine SSN 778 Receives New AM 3D Printer." ***Naval Technology***, February 27, 2023. https://www.naval-technology.com/news/us-ssn778-am-3d-printer/.

56 Cancian, Mark F, Matthew Cancian, and Eric Heginbotham. "The First Battle of the Next War. Wargaming a Chinese Invasion of Taiwan." Center for Strategic and International Studies. January 9, 2023.

Information Advantage

The last of the Joint Warfighting concepts is the most nebulous: Information Advantage. However, it may turn out to be the most important, especially given that degradation and disruption are endemic features of future warfare. In 1980, Alvin Toffler's published his best-selling book "The Third Wave", which tried to foresee a world when Information Technology and Information supplanted the industrial age as the driver of the economy and warfare, just as the industrial age supplanted the agrarian dominated social structure in the late 1880's. In the 43 years since Toffler's book, his vision has become a reality. Simply put, while platforms are still important, and the military must have kinetic capability, successful employment of different lethal and nonlethal capabilities is increasingly dependent upon the information domain. This is the bedrock of the Information Advantage pillar for all domain operations. Information Advantage envisions a world where speed to decision and accuracy of information become the variables the military needs to maximize in order to gain both the tactical and strategic advantage. The key parameters are decision advantage and influence operations—and both are part of Information Advantage.

Information Advantage will, likely, be predicated on the ability to acquire and access data from all sources and modalities (to include HUMINT, SIGINT, etc), fuse the data into a single picture, then apply advanced analytics and AI/ML, and military judgment to support the timely decision making. This is true at every echelon, from individual combatants to the campaign and strategic levels of warfare.

Information Advantage underlies JADC2, Joint Fires, and Contested Logistics. Ultimately, its foundation is the sharing, fusing and presenting of information between commanders, subordinates, and appropriate partners and allies. In a war, critical information pertains to where one's forces are, where enemy forces are, where other relevant actors are, the state of those actors or forces, and what environmental factors might affect operations. This is commonly described as situational awareness or situational understanding. Information Advantage also encompasses command and control, specifically the ability to communicate and transfer data. This initiative recognizes there are delays inherent in command and control. As relevant data is received, analyzed, and dispersed, there is a delay between battlefield headquarters and subordinates that implement a commander's orders.

Information Advantage is the outcome of the interconnectivity between operational forces and their sensors. It is dependent on the transfer of information between individuals and groups up and down the chain of command. This concept entails integrating both new and old information into meaningful insights and making those insights available to relevant personnel. While the process of identifying data, analyzing it, and acting upon the information is not revolutionary, the ability to get the right information into the hands of the right operator across multiple Services is a significant operational advantage.

Information Advantage should be understood as gaining a temporary edge over the adversary through superior decision-making tempo. As such, Information Advantage enhances the effectiveness of DoD by executing the decision-making process more quickly and disrupting an adversaries' ability to take timely meaningful actions. The ability to have an expanded situational awareness and increased decision tempo – in turn – causes the degradation of an adversary's ability to make decisions at an operationally relevant pace, potentially reducing their effectiveness in the battlespace.

Although planning at the operational level is sometimes conducted jointly, the traditional command and control system operates independently within each Service because of intra-Service rivalries, and the value that the U.S. military places on local operational control at lower tactical organizational levels, where tactical execution takes place. Once a mission has begun, pulling in another Service usually requires contacting the operational level of command, a labor-intensive and time-consuming step.[57] To enable Information Advantage, the military can best achieve its goals when commanders grow comfortable delegating authority to junior officers or senior enlisted personnel from any Service in the U.S. military. Often, Service control is not practical when battlespaces are large. Instead of seeing conventional command and control as belonging to a particular Service, the U.S. military should think of C2 nodes as joint entities that can draw on personnel from different Services depending on the given mission. These nodes should be structured to enable mission flexibility, where shifts in desired effects can happen over a relevant time scale. Service equipping and training plans must be modified to support these joint capabilities.

Additionally, instead of aiming for information dominance through ubiquitous connectivity, DoD should seek Information Advantage by being able to operate with degraded systems more effectively than competitors. The overly simplistic goal to "Connect any sensor to any shooter" increases system complexity and potentially creates bureaucratic drag. Seeking dominance – rather than advantage – proliferates unrealistic expectations and complicates requirements.

Information Advantage is about speed and accuracy of information to achieve decision dominance or superiority over the adversary. Being superior in this aspect of warfighting will enhance the probability of success of U.S. and allied forces.

NDIA ETI Information Advantage Panel

During the NDIA ETI panel, the panelists reiterated that Information Advantage is fundamentally about solving operational problems. The core driver is the need for interoperability, where warfighters have multiple options for obtaining the information they need for different missions in an electromagnetically contested environment.

Dr. George Ka'iliwai, U.S. Indo-Pacific Command Director of Resources and Requirements, began the panel by describing some of the solutions DoD has operationalized to ensure decision superiority. At Indo-Pacific Command, Dr. Ka'iliwai described needing to optimize synchronized execution of operations in the information environment across all tiers, which is "employed as desired with kinetic capabilities

57 Cowie, Leland and Graff, Todd, et. al. "To Build Joint Command and Control, First Break Joint Command and Control." War on the Rocks. July 2, 2021. https://warontherocks.com/2021/07/to-build-joint-command-and-control-first-break-joint-command-and-control/.

to achieve force multiplying effects." Dr. Ka'iliwai focused his remarks on C2 of the information environment, specifically referencing the use of a Global Integrated Operations Support Platform, which is being used as a visualization tool for monitoring and assessing global campaign activities. This allows his staff to coordinate operations, activities, and investments across all global domains and to categorize and identify key activities in support of global campaign plans.

Dr. Tim Grayson, Special Assistant to the Secretary of the Air Force for Operational Imperatives, opened up the panel emphasizing his role is fundamentally about solving operational problems. In the operational environment, much of this is focused on how data "actually" wins a war. As such, it is crucial to focus on "what warfighters and operators are going to do with the data, how they use the data to make decisions, and the decision advantage that comes out of that." Dr. Grayson specifically cited the need for software-defined networking, enabling warfighters to quickly add and subtract formatted types of RF signals and data formats. He mentioned DoD's long-term efforts to develop joint software-defined radio systems and programs.

In his opening remarks, Major General Matt Easley, Deputy Principal Information Operations Advisor to the Under Secretary of Defense for Policy, explains how Information Advantage fits into DoD's National Defense Strategy, "Information plays a key role in showing how these three concepts [campaigning, integrated deterrence, and building enduring advantages] work together to create a more secure world. What our intentions are in a campaign, how we act with allies to create deterrence, and how we train and modernize our forces to build these enduring advantages."

Dr. Kelly Fletcher, DoD Principal Deputy Chief Information Officer (CIO), built on the previous panelists' comments by articulating how the CIO is focused on protecting the information and data that Dr. Grayson described. The CIO also has the lead in DoD for positioning, navigation, and timing (PNT). To maintain the information dominance in contested environments, Dr. Fletcher spoke about how terrestrial and undersea capabilities ensure that information and data does not stay static. Through partnering with the Space Force and leveraging commercial satellite communications, DoD will be able to bring greater throughput "right up to the edge." CIO's efforts also include modernizing DoD's GPS constellation and moving beyond space-based capabilities and incorporating alternatives and complements to the GPS system to ensure that the warfighter is able to "select the next best signal."

Information Advantage Technology Enablers

Enhanced on-sensor processing: The precursor to Toffler's Third Wave was his 1970 book "Future Shock," in which he argued that unaided, the amount of information available to any decisionmaker could quickly overwhelm the operator. One necessary capability to prevent information overload is to not transmit superfluous or unprocessed data. Rapidly analyzing data on sensor, and discarding data locally will reduce the bandwidth needed to transmit data and reduce the complexity of data that is analyzed. Continuing to develop automated capabilities to turn data into useable information is a key first step.

Ubiquitous Information Access: One of the first lessons learned from the War in Ukraine is the value of "ubiquitous" internet access. In Ukraine, this was attempted through "Starlink" – the Space-X commercially proliferated LEO network. This system consisted of over 3,500 small satellites providing high band width internet access from space to a mobile terminal, a capability that became the backbone of communications for the Ukrainian military and government.[58] Ubiquitous internet may use networks of proliferated LEO constellation augmented by ground-based networks. The Space Development Agency is starting to build out their Transport Layer, which serves as a satellite constellation consisting of several hundred satellites for resilient, low-latency military data and connectivity usable for a wide range of warfighter platforms.[59] While there is a tremendous opportunity for DoD to leverage space-based assets, including commercial satellites, the warfighter will have greater capabilities by incorporating alternative solutions such as undersea cables. The foundation of DoD's precision, navigation, and timing capabilities is its GPS system, which the Department is working to modernize. However, synchronizing across ground-, undersea-, and terrestrial-based technologies will give warfighters resilient and alternative options for obtaining information needed to execute different mission sets.

Having ubiquitous information available is the supply side of Information Advantage. The DoD will also need to work on the application side:

Artificial Information / Decision Aid Tools on Demand: Coincident to having more data available, combat elements will need to develop tailored decision aids using AI and ML tools to discern potential signal from noise. This process will start at the sensor level, where embedded processors will discern the potential significance of collected information to reduce the total volume of the data passed. It will also require a shift in how and where the software is updated. Just as the Air Force's Kessel Run's division demonstrated the ability to quickly build software, future combat elements will require dedicated software coding teams, either forward deployed or in connectivity with leadership to tune algorithms and decision aids for the force.[60] This workforce need is similar to personnel that are essential for continuously maintaining, repairing, and upgrading physical systems and platforms.

Trust in information is the single most important characteristic of Information Advantage. While decentralizing control to lower echelons enables more rapid decision-making as information and command systems degrade, an inability to trust information systems will minimize multi-domain capabilities. Co-locating sensors, shooters, and commanders down the chain of command is necessary, however this decentralized command system becomes vulnerable to electromagnetic spectrum threats or jamming. On the other hand, decentralized decision authority could enable more distributed operations, rather than physically co-locating assets. This is a key point of the Defense Advanced Research Project Agency's (DARPA) Mosaic

58 Iyengar, Rishi. "Why Ukraine is Stuck With Elon (for Now)." Foreign Policy. November 22, 2022. https://foreignpolicy.com/2022/11/22/ukraine-internet-starlink-elon-musk-russia-war/

59 "When we talk about what will enable JADC2, we're really talking about the Internet of Warfighting Things." Breaking Defense. March 22, 2023. https://breakingdefense.com/2023/03/when-we-talk-about-what-will-enable-jadc2-were-really-talking-about-the-internet-of-warfighting-things/

60 Obis, Anastasia. "How Software Factories Position DOD to Win." GOVCIO, April 28, 2023. https://governmentciomedia.com/how-software-factories-position-dod-win

Warfare concept, which pushes the idea that disaggregated manned and autonomous units guided by human command with AI-enabled machine control would enable U.S. forces to execute more numerous and diverse courses of action compared to today's military.[61]

Electronic attacks are designed to disrupt, deny, or deceive an adversary's data. Electromagnetic warfare is particularly relevant for near-peer competition. Chinese strategy is contingent upon targeting information systems and degrading U.S., allied, and partner forces cognitively. Communication cannot be fragile; resilience is paramount to successful decision-making. The technical ability to gather and share information is useless without the ability to trust it, convey it to the right audiences, make sound decisions, and take actions based on it. Simply having many sensors, better analytic capability, or systems that update more rapidly is not enough. Information Advantage also includes cognitive processes, trust in the quality of machine analyses, and trust between organizations central to those processes.

Automated Target Recognition (ATR). The expansion of sensing modalities being used in theater (acoustic, optical, infrared, Conventional and Synthetic Aperture Radar from space, air, land, and undersea), is increasing the challenge for analysts to differentiate target signal from background noise. Analysts need help discerning, for example, physical characteristics, fixed and moving target indicators, and change analysis–all of which can queue the operator as to where targets or activity of interest might be. The United States must continue to expand ATR capabilities, especially through the use of AI/ML algorithms.

Social Network Analysis: Social media is playing and important and increasing role in supporting military information operations. Capabilities are needed for conducting nodal analysis on social networks to understand who the "influencers" are and the impact they would have on will of both the people and military. For example, the ability to share information surrounding Russian activity before, during, and after their invasion proved to shape the public's understanding of how the conflict has taken place. The Ukrainian military's use of social media for tactical advantages (e.g., tracking Russian troop movements) should be mirrored and replicated in U.S. intelligence analysis. Today, almost 60% of global internet traffic is pushed over mobile devices, offering a rich opportunity for those able to effectively make use of the data.[62]

Relatedly, the advent of social media has fueled influence campaigns, whereby one adversary may use fabricated stories and facts on social media in hopes to impact the will of the people. In fact, open-source information helped refute false flag narratives from Russia, serving as a counter to Putin's own narrative about the war. Sorting truth from fiction must be a large part of any effort to gain Information Advantage. In support of this effort, the Army recently tested an AI tool that examines open-source social media data for bot detection and discovers deep fake algorithms to determine if social media activity that is posted within a commander's area of responsibility is artificially generated.[63] This capability allows commanders to better understand the social media environment, which gives them greater awareness of their battlespace.

Commercial Cloud Services: The emergence of cloud computing as a capability will enable DoD to move data across agencies and classification levels at unprecedented speed. As Major General Easley remarked,

> ***We see [cloud-based infrastructure] as one of the key abilities to be able to collect, process and analyze this information environment at a global scale.***

Information-sharing is historically difficult within DoD, often limited by bureaucratic processes or size, weight, and power constraints. However, the demand for information by warfighters is clear and was emphasized during the NDIA ETI panel. Greater information will enable warfighters to derive better tactical outcomes. As a contracting vehicle, DoD's Joint Warfighting Cloud Capability (JWCC) looks to acquire commercial cloud capabilities and services that could enable smooth data exchanges at scale without the need for complex network constructions. Clouds are unifying capabilities through increasing collaboration and interoperability across security levels as well as coalition partners. The ability for DoD to retain and easily share information from the strategic level to tactical warfighters is a concrete competitive advantage enabled by commercial cloud services.

Information Security: Information underlies everything in a conflict. Cybersecurity is key to protecting critical data against threats such as jamming or potential adversarial corruption of friendly data streams. Information security activities need to protect operational and industrial base data. However, it is not just specific to protecting service networks, but also includes their weapon systems. Modern cryptology solutions are helping DoD in this regard. To remain ahead, implementation of quantum-resilient cryptography is vital. Moreover, in November 2022, DoD's Chief Information Officer released a Zero Trust Strategy, which outlines four high-level strategic goals DoD will take by FY 2027 to reduce the attack surface, enable risk management and effective data-sharing in partnership environments, and quickly contain and remediate adversary activities.[64] It also extends to information coming from the various combat support agencies and defense industrial base partners. In November 2021, DoD announced the Cybersecurity Modernization Model Certification 2.0 program,

61 For more information on Mosaic Warfare, two helpful resources include the Center for Strategic and Budgetary Assessments' report on Mosaic Warfare here: https://csbaonline.org/uploads/documents/Mosaic_Warfare.pdf and the Hudson Institute's report on Decision-Centric Warfare here: https://s3.amazonaws.com/media.hudson.org/Clark%20Patt%20Walton_Implementing%20Decision-Centric%20Warfare%20-%20Elevating%20Command%20and%20Control%20to%20Gain%20an%20Optionality%20Advantage.pdf.

62 For more information on the rise of mobile device website traffic worldwide, visit here: https://www.statista.com/statistics/277125/share-of-website-traffic-coming-from-mobile-devices/.

63 Pomerleau, Mark. "Army Tests Tool for Detecting Bots on Social Media." DefenseScoop (blog), July 31, 2023. https://defensescoop.com/2023/07/31/army-tests-tool-for-detecting-bots-on-social-media/.

64 Department of Defense, Chief Information Officer. "DoD Zero Trust Strategy." November 7, 2022. https://dodcio.defense.gov/Portals/0/Documents/Library/DoD-ZTStrategy.pdf

which is an assessment standard designed to ensure that defense contractors are compliant with current security requirements for protecting sensitive defense information.[65] This effort protects the information flowing to the Department before it is consumed.

Summary

Achieving Information Advantage is no easy task. The United States is just now developing underlying techniques to acquire, fuse, (machine) analyze, provide recommended courses of action, and do so faster than current decisions are made. While challenging, the problems are tractable, and would provide a huge advantage. There are two ways to achieve Information Advantage

1. Prepare and present information more quickly to your forces than your adversary
2. Degrade adversary information processes

An intrinsic problem to achieve Information Advantage is the span of information. DoD is actively working to determine what operators are going to do with data, how they use data to make a decision, and what concrete advantage comes out from this process. Ultimately, new data processing technologies and resilient connectivity

Cross-Cutting Issues

The Joint Warfighting Concept for All Domain Operations is a bold concept comprising many challenging elements. While this paper concentrates on the technological aspects, technology alone is not enough. Effective implementation will couple the technical changes with doctrinal, force structure and cultural changes. All are needed. Recall, the motivation for the Joint Warfighting Concept is that in numerous wargames not using these the United States was getting soundly defeated by the Chinese in the Taiwan Straits fight. Several technological elements seem to bubble to the top, and for the most part, these technologies are not platform centric. It is important to realize that there are several technological elements that stand out, which are not platform centric, but rather, enterprise-level, joint technology enablers.

Foremost among these is the need to continue to develop AI/ML tools to ease decision-making at the edge. In reality, this is really an ability to access an enormous amount of data, process this data quickly, and assist the decision maker. The DoD recognized this with the formation of the Joint Artificial Intelligence Center (JAIC) in 2018. One of the problems with the JAIC was that it was a standalone element. Investments in AI need to be done much more broadly, but focused on specific problems. Second, Spectrum Dominance is also an underlying element to success of all four of the Joint Warfighting Concept. Electronic warfare, allied communications, or any other electromagnetic energy that moves through the environment, having the ability to operate in a contested environment will provide substantial advantage to allied forces. As sensors and data becomes more ubiquitous, microprocessor devices will advance the capability to sense and process data at the point of collection to reduce distribution of unnecessary data. Fused sensors will allow allies and partners to get to the decision faster, and getting to the decision faster will ultimately result in a tactical advantage for the side that possesses the ability to sort data most quickly. Although not discussed as an enabling technology for any of the four Joint Warfighting Concept, there is one continuing issue with the way the U.S. and allies develop capabilities. Simply, the DoD and allies have not yet fully embraced open systems architectures and digital engineering. Adoption of these two technical characteristics will allow more rapid and effective system upgrades, allowing the United States and allies to remain at the "leading edge."

Panelists reiterated throughout all NDIA ETI panels how the PPBE process is a significant barrier to successfully building solutions for operating in a contested environment. The process serves as a framework for DoD civilian and military leaders to decide which programs to fund based on strategic objectives and produces the Department's portion of the President's annual budget request.[66] It is widely criticized as increasing barriers for integrating new technologies into the Services in a timely manner and favoring large capital expenditures.[67] The process does not provide the flexibility and timeliness needed for integrating modern commercial technology, enterprise level services, or to transition disruptive technologies developed within DoD programs. Nor does it allow leadership to easily prioritize joint capabilities over Service-centric and platform centric efforts. The budget structure limits industry's ability to see how DoD plans to invest in joint efforts, such as JADC2. Additionally, the current PPBE process makes it difficult for the Services to move away from funding pre-planned programs based on a budget that was made years ago, where there may have been different priorities, technological opportunities, threats, or budget constraints. Due to the current nature of technology, it may be time to develop a parallel "digital acquisition system" alongside the well-know and slow platform acquisition system so that software, digital updates, and AI/ML algorithms can be more rapidly delivered to warfighters.

65 Department of Defense, Chief Information Officer. "About CMMC." dodcio.defense.gov/CMMC/about/.
66 "DOD Planning, Programming, Budgeting, and Execution (PPBE): Overview and Selected Issues for Congress." Congressional Research Service, July 11, 2022. https://crsreports.congress.gov/product/pdf/R/R47178#:~:text=The%20U.S.%20Department%20of%20Defense,defense%20agencies%2C%20and%20other%20components.
67 Ibid.

Recommendations

To achieve the vision of the Joint Warfighting Concept, this paper proposes ten recommendations, which are specifically intended to:

1. Mature emerging technologies
2. Accelerate the adoption of new capabilities
3. Address a specific operational need

Many of the following recommendations came directly from the NDIA ETI panels.

1. Publish an unclassified version of the Joint Warfighting Concept. Releasing an unclassified version of the JWC will help DoD be more transparent with industry. This idea is intended to give industry a better understanding of DoD's operational challenges, which will ultimately lead to solutions that effectively meet the capabilities DoD wants.

2. Integrate space-based assets from DoD agencies and intelligence community into decision-making networks for warfighters. In a time of war, the National Geospatial Intelligence Agency (NGA), Defense Intelligence Agency (DIA), Defense Information Systems Agency (DISA), and National Security Agency (NSA) become Combat Support Agencies. As it stands, these agencies' data is not tactically available to the warfighter in real-time. Their space-based ISR should be integrated and accessible. This will require the agencies to make their own data available and must be able to operate in a contested, degraded, and operationally limited environment. Data standards are equally important to advanced networking. If sensors are to share warfighting-relevant information, the data must be structured to ensure it is universally compatible. Moreover, advancing the capability to sense and process data at the point of collection to reduce distribution of the unnecessary data will enable faster decision-making, resulting in a tactical advantage.

3. Invest in Modeling and Simulation (M&S) tools to support the development, integration, and transition of next-generation solutions. Among the greatest needs is the ability to evaluate innovations, incubate prototypes, and validate capabilities to accelerate the transition of advanced technologies to rapid fielding or programs of record. To prepare for high-end conflict, DoD should prioritize operational analysis to support JWC's focus on System of Systems. It is equally important to ensure the lessons learned from M&S is incorporated back into the design and development process for new capabilities. There are both formal and informal ways of collecting feedback. However, it is imperative that each Service has a formal process for collecting, tracking, and incorporating this feedback. This process will enhance technical inputs and realities as well as future costs, all of which are necessary for the requirements process.

4. Increase adoption of modular open-system architectures (MOSA), digital materiel management, and digital engineering practices. It currently takes too long to modify or fix hardware-based systems, with turnaround times taking 5-10 years. Adoption of these two technical characteristics will allow more rapid and effective system upgrades. For example, the U.S. Marine Corps is focusing on more modular, reprogrammable, and rapidly deployable systems for specific missions.[68] Their approach is designed to ensure all elements can fight in a degraded command and control environment. While Modular Open System policies and statutes are in place, they are too easily waived. Moving forward, it is recommended any waivers require approval by both the Under Secretary of Defense for Acquisition and Sustainment and relevant Service Secretary.

5. Tie joint exercises to funding. One of the primary ways the Joint Requirements Oversight Council (JROC) assesses joint military capabilities is through exercises, wargames, and table-top exercises. A key takeaway from the NDIA ETI panels is the need to expand experimentation for new technologies in simulated contested environments during field and fleet exercises. It is imperative to plan for operating with a smaller footprint, and scaling up the technologies that help warfighters achieve their military objectives. When experimenting with new technologies during joint exercises, funding should be available for successes in the following fiscal year to help support the transition into programs of record and procurement. Moreover, incentives should be provided to push the services to focus on jointness over service-unique capabilities.

6. Pre-position forces and material to improve the mobility and sustainability of U.S. forces. This would also include pre-positioning critical items in anticipation of requests to reduce delivery time. While this creates a risk of oversupply, this far outweighs the possibility of slowing operations because of a lack of supply. From the NDIA panel, last mile delivery has been identified as a current shortfall. Closer integration of U.S. military logistics systems with those of allies and partners can help minimize reliance on external supply and vulnerable infrastructure. A key takeaway is finding ways to source supplies from rotational or permanent source bases. This operational challenge also presents a unique opportunity to experiment with technologies needed for predictive logistics and leverage commercial partner logistics assets to build resiliency into the supply chain. This may include gaining access to basing, storage, or relationships with ports that DoD does not have access to. This paper focused on technology without addressing element like force posture and structure changes. While force structure changes are implied, this is for another paper.

68 Department of the Navy, United States Marine Corps. "Force Design 2030." Department of Defense. March 2020. https://www.hqmc.marines.mil/Portals/142/Docs/CMC38%20Force%20Design%202030%20Report%20Phase%20I%20and%20II.pdf

7. Assign responsibility to a service for intra-theater lift in the Pacific. The Department of Defense should be clear about how it will meet the need for intra-theater lift and which service will provide it. Intra-theater lift is not a function that falls under U.S. Transportation Command, which controls movements from the continental U.S. to in-theater ports.[69] Intra-theater lift refers to the delivery of materiel from the point of debarkation to an operational unit. While each service has a history in logistics and are implementing their own initiatives to address the challenges of Contested Logistics, no service has been assigned responsibility for providing intra-theater lift capabilities in the Pacific.

8. Pursue basing agreements for logistical and operational needs with partners in Southeast Asia. These could include Malaysia, Indonesia, Vietnam, Brunei, and Thailand. The goal should be to develop a broader network of reliable bases and logistical nodes to sustain equipment and personnel in forward-deployed locations. Within the First Island Chain, the U.S. should avoid dependence on large, fixed installations. Commercial partners have a key role to play and can help build in resiliency. DoD must leverage storage facilities, ports, and relationships that its industry partners have.

9. Commit to consistent munitions purchases for high-priority munitions. The war in Ukraine keeps the DoD hopeful that consistent purchases can send a strong demand signal to industry to increase the production of key precision-guided munitions. These include the Long-Range Anti-Ship Missile, Joint Air-to-Surface Standoff Missile Extended Range, the Standard Missile-6 and the Advanced Medium Range Air-to-Air Missile. However, this may prove to be difficult as Congressional appropriators remain skeptical of multiyear procurement authorities. With appropriate justification for cost savings and improved speed of delivery, DoD and Congress can work on appropriate use of multi-year procurement authority. Multi-year munition procurements are yielding positive results, which can be seen, for example, through the Army's purchase of Excalibur shells – a GPS-guided artillery shell.[70]

10. Develop a plan, including responsible organizations, funding requirements, transition plans, and priorities for the development or leveraging of advanced technologies for Joint Warfighting Concept, making use of science and technology, SBIR, and other research and development funding. The objective is to ensure that the S&T activities DoD previously had a Joint Warfighting Science and Technology Plan (JWSTP), which documented DoD's joint S&T vision, strategy, and plan. These documents were a collaborative product of the Office of the Secretary of Defense (OSD), Joint Staff, military services, and defense agencies. These kinds of plans need to be reflected in the budget requests of the Services and Agencies or they have limited value given the effort required to develop them.

Conclusion

The Joint Force faces an uncertain future, confronting long-term strategic competition with Russia and China, rogue states pursuing nuclear weapons, and violent extremist organizations. The four Strategic Imperatives – JADC2, Joint Fires, Contested Logistics, and Information Advantage – have been highlighted as key operational concepts required to counter potential Chinese aggression against Taiwan. While the Joint Warfighting Concept was developed with the Indo-Pacific theater in mind, the goals outlined by each Strategic Imperative can be applied to all environments. Capabilities such as faster decision-making loops, accelerated targeting cycles, synchronized fires, and route optimization for logistics operations have tangible benefits to warfighters regardless of geographic boundary. Agility across all domains will be a key to success in any 21st century fight in addition to interoperability with allies and partners as well as within different classification levels. New technologies are providing DoD with the opportunity to achieve JWC's envisioned goals, which will differentiate JWC from previous visions for the Joint Force. However, DoD will have to navigate systematic stovepipes and its current budgeting process to ensure the services have the ability to fight across domains and are technologically equipped to meet mission objectives. Ultimately, joint industry-DoD solutions will help drive the modernization of each service while the JWC provides a unifying roadmap to turn the U.S. military into an interoperable and multidomain capable force.

69 Martin, Bradley, and Christopher G Pernin. "The Problem of Intra-Theater Lift: Moving Things Around in the Pacific Area of Responsibility." The RAND Blog, RAND Corporation, 6 Sept. 2022, www.rand.org/blog/2022/09/the-problem-of-intra-theater-lift-moving-things-around.html.

70 Eaglen, Mackenzie and Greenwalt, Bill. "The Army's multiyear contracts are a model for other services." DefenseNews. February 3, 2023. https://www.defensenews.com/opinion/commentary/2023/02/03/the-armys-multiyear-contracts-are-a-model-for-other-services/

Annex

NDIA ETI Panel Events

Panel Moderator: Alan Shaffer, Distinguished Visiting Fellow, NDIA ETI, and former Deputy Under Secretary of Defense for Acquisition & Sustainment

JADC2 (February 24, 2022)

- Retired Brigadier General Richard "Scott" Stapp: Former Vice President of Capabilities and All Domain Integration, Former Chief Technology Officer, Northrop Grumman
- Mr. Anthony Smith: Acting Principal Deputy Director Command, Control, Communications and Infrastructure for the Department of Defense Chief Information Officer
- Dr. Michael Zatman: Former Principal Deputy Principal Director for Fully Networked Command, Control and Communications, Office of the Under Secretary of Defense for Research and Engineering

Joint Fires (April 14, 2022)

- Vice Admiral Ron Boxall: Former Director, Force Structure, Resources, and Assessment, Joint Chiefs of Staff (JCS-J8)
- Mr. Chris O'Donnell: Acting Principal Deputy Assistant Secretary for Acquisition, Platform and Weapon Portfolio Management
- BG John Rafferty: Current Army Chief of Public Affairs, Former Director, US Army Long Range Precision Fires CFT
- Dr. Arthur Mabbett, Senior Vice President & Operations Manager of Leidos, and formerly the Program Manager at DARPA and the Navy for the Long-Range Anti-Surface Munition

Contested Logistics (July 14, 2022)

- Mr. Steve Morani: Principal Deputy Assistant Secretary of Defense for Sustainment, Office of the Undersecretary of Defense for Acquisition and Sustainment
- Ms. Kristina O'Brien: Current Deputy to the Commanding General of the Military Surface Deployment and Distribution Command, Former Principal Deputy Director for Logistics on the Joint Chiefs of Staff
- Mr. Terrence (Terry) Emmert: Principal Deputy Chief Technology for Mission Capabilities in the Office of the Under Secretary of Defense for Research and Engineering, Assistant Secretary of Defense for Mission Capabilities (Acting), Office of the Under Secretary of Defense for Research and Engineering
- BG Gavin Gardner: U.S. INDOPACOM Director of Logistics, Engineering, and Security Cooperation (J-4)

Information Advantage (October 12, 2022)

- Dr. George Ka'iliwai: U.S. INDOPACOM Director of Resources and Requirements (INDOPACOM J-8)
- Dr. Kelly Fletcher: Department of State Chief Information Office, Former Principal Deputy Department of Defense Chief Information Officer
- Dr. Tim Grayson: Special Assistant to the Secretary of the Air Force for Operational Imperatives
- MG Matt Easley: Deputy Principal Information Operations Advisor to the Under Secretary of Defense for Policy

EMERGING TECHNOLOGIES INSTITUTE

SUPPORTING EMERGING TECHNOLOGIES TO SECURE U.S. NATIONAL DEFENSE AND ADVANCE U.S. ECONOMIC STRENGTH

The National Defense Industrial Association's Emerging Technologies Institute (ETI) performs research, hosts events, and bolsters public awareness through educational products and webinars focused on defense technology modernization and innovation. ETI also works to create a policy environment most conducive to the efficient development and delivery of new systems and technologies for the defense enterprise. ETI engages industry, academia, policymakers, and the public to explore emerging technologies' impact on national security and opportunities for industry-government partnerships to increase U.S. competitive advantage.

ETI reports, events, and workshops support NDIA's membership and the defense science & technology enterprise as part of its nonpartisan 501(c)(3) mission.

ETI was founded in 2021 and is staffed by researchers and subject matter experts and backed by a preeminent advisory board.

For more information, visit **EmergingTechnologiesInstitute.org**

EMERGING TECHNOLOGIES INSTITUTE

EmergingTechnologiesInstitute.org