Industry Study Report

for

Command, Control, Communications, Computer, Intelligence, Surveillance, and Reconnaissance (C4ISR)

A Review of the C4ISR Industry Efforts to Implement the Concept for Joint All-Domain Command and Control (JADC2)

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Executive Summary

After the 2018 National Defense Strategy (NDS) release, the Joint Staff endeavored to modernize and enhance the U.S. global integrated defense posture and joint capabilities and concepts. The NDS recognized the emerging Great Power Competition (GPC) and refocused the Department of Defense's (DoD) priorities. The Combatant Commands (CCMD), who report directly to the Secretary of Defense (SecDef), maintain theater-specific defense partnerships and force postures to respond to threats in their areas of responsibility. However, the strategic environment described in the NDS demanded transregional approaches and joint, All-Domain capabilities. Over the last four years, the resultant modernization efforts within the Services and the Joint Staff's concept development for warfighting concepts to support the CCMDs intersected. The Joint All-Domain Command and Control (JADC2) concept emerged as the framework to connect the people, systems, and warfighting concepts.

Despite considerable progress in initializing and organizing JADC2 efforts, implementation is impeded by the slow institutionalization of JADC2. The evolution of JADC2 as an integrating framework for the DoD is complex because it originated in multiple places. Each Service, CCMD, and acquisition agency assessed that the interconnected and data-driven decision-making environment demanded new ways and capabilities to win decisively against increasingly capable adversaries doing the same. In this way, JADC2 is a grassroots effort with top-down integration and standardization within the DoD. The Command and Control (C2), Communication, Computers, Intelligence, Surveillance, and Reconnaissance (C4ISR) industry is adapting to support the new JADC2 market demands.

This report summarizes these efforts and how the defense industry is responding to support JADC2 efforts. It assesses the current JADC2 framework as an integrating effort for the new joint concepts. It provides an overview of the C4ISR industry supporting the JADC2 framework. It analyzes the Research, Development, Test, and Evaluation (RDT&E) public and private innovation centers' response to support JADC2 development. It concludes with recommendations for the DoD senior leaders and Joint Staff to implement and support JADC2 institutionalization. It also offers advice for future engagement with industry and innovation centers on JADC2 requirements and market participation.

The Industry Study found four common themes throughout the field studies. (1) There are multiple nuanced interpretations of the direction and vision of JADC2. (2) Industry and innovation centers are engaged and supporting JADC2 efforts. (3) Policy and organizational obstacles are impeding action. (4) JADC2's bottom-up approach is best, but it requires top-down coordination. The group offers recommendations to focus and engage the traditional and non-traditional defense industry partners to achieve the JADC2 purpose. These recommendations are centered around the JADC2 Lines of Effort (LOE). There are actions that both the DoD and the industry partners must take together to make meaningful and timely progress.

The C4ISR IS team focused on industry's response to JADC2 implementation and its understanding of the JADC2 framework through targeted engagements with C4ISR-supporting firms, education centers, and laboratories. The field studies confirmed that industry and innovation centers are responding rapidly to meet the new JADC2 demand signals. Across the DoD, DIB, innovation hubs, and educational institutions, leaders and innovators seek to advance the

objectives of JADC2; however, they do not fully understand to what end. The C4ISR team offers insights into industry and DoD's efforts to make progress. The team's findings and industry inputs confirmed that implementation efforts thus far have robust, innovative approaches but have uncertain results due to a lack of JADC2 institutionalization across Services and CCMDs. The lack of institutionalization slows industry's progress in advancing concepts into production. It also risks missing opportunities to bridge potential solutions across the acquisition system's valley of death.

The five key areas of common impediments hindering industry's support for JADC2 are (1) limitations within the DIB operational environment and ecosystem; (2) the development of reference architecture and standards for JADC2 implementation; (3) common misunderstandings of JWC's and JADC2's concepts and approaches; (4) challenges with communication and culture; and (5) policies and organizational design supporting a unified JADC2 effort. The Joint Staff leaders guiding the JADC2 efforts have significant opportunities to curate the current progress gained by innovation centers and industry by institutionalizing JADC2 standards, policies, and culture and synchronizing JADC2 efforts across CCMDs and Services.

JADC2 is not just a framework, integrating activity, or concept. It is not just a platform or a component resourced in a program of record. It is all these things but also a cultural mindset that accounts for a sense, make sense, and act strategy in every resourcing and warfighting decision. The JADC2-supporting market is postured to rapidly respond to the institutionalization of the concept. The firms and innovation centers in this market can provide the necessary technological solutions for the JADC2 framework to enable Joint Forces to win decisively in any environment.

***Disclaimer**: The report is derived from open-source information and insights taken from public and private defense organizations. The research and analysis conducted relied upon open-source data for the findings. Classified programs supporting C4ISR and JADC2 are not referenced in this industry study. Observations contained in this report are informed by business and proprietary information. For the purposes of protecting such information, insights are not directly attributed and are compiled with multiple firms' feedback when possible. References to specific programs are based on publicly available information and financial statements.*

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C4ISR Industry Study Report on the JADC2 Implementation and Industry

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"The Joint Warfighting Concept (JWC) guides how we organize, train, and equip the Joint Force… Among the enablers for JWC, Joint All Domain Command and Control (JADC2) is a warfighting capability to sense, analyze, and act at all levels and phases of conflict, across all domains, and with partners, to deliver information advantage to our forces and decision-makers at greater speeds than our adversaries can react."

– GEN Mark A. Milley, Chairman of the Joint Chief of Staff, April 2022

Russia's conflict in Ukraine provides unambiguous evidence that America's adversaries are growing increasingly emboldened. Winning in strategic competition and preventing future conflict requires the right investments and investment strategy now. In 2019, the Joint Staff began developing the Joint Warfighting Concept (JWC) to address the ever-changing character of war in a way informed by the US assessment of the potential future operating environment. Services and CCMDs developed bottom-up approaches to achieve Joint All-Domain Command and Control (JADC2) as an integrating enabler to win in competition and conflict. JADC2's evolution and concept development created a new market and capability requirements for the defense industry, innovation centers, and other stakeholders.

Core Problem Statement for Industries' Implementation of JADC2. To succeed in the current and anticipated future global environments of varied peer and non-peer threats and challenges across all domains, the Joint Force developed the JWC, Joint Concepts (JC), and JADC2 to evolve and to prepare the Services to provide the appropriate and necessary forces and warfighting capabilities to the CCMDs. Creating this Joint Force of the Future requires a deliberate and unified process of **initialization**, **implementation**, and **institutionalization** of concepts that accounts for the disparate yet common Service communities within the Department of Defense, other government agencies, allies and partners, and the Defense Industrial Base (DIB). With Command and Control (C2) as the central warfighting function necessary to achieve objectives across any spectrum of conflict and unite the Service communities as one, the Joint Staff's initialization of JADC2 began with the development of the concept and publication of the strategy. JADC2's implementation is underway with various Service efforts, allied and partner demand signals, DIB actions and interests, and research and development efforts. Nevertheless, integration of these efforts and the other efforts needed to achieve ultimate JADC2 institutionalization remain absent. Institutionalizing the tenets of the JADC2 concept requires further unification of efforts through evolving defense acquisition policy for a higher tempo process, defining of shared standards for the Services, identifying and delegating the authorities needed to a lead integrator, and developing a common doctrine to unite the disparate Service communities and to prevent years of inefficiency and inescapable bureaucracy.

Methodology and Approach to Address the Problem. The following report assesses industry and defense partners' response to the new JADC2 market and how they are advancing and implementing the JADC2 strategy and implementation plan. The approach to answering the

underlying problem statement is to consider how well the DoD synchronizes and coordinates industries' efforts by institutionalizing JADC2 policies, standards, communication, culture, education, and organizational structures across the Services and CCMDs. This report recognizes considerable progress to move forward quickly and advance innovation in new ways. In doing so, the industry study team offers insights, observations, and recommendations on how these innovative approaches impact industries' ability to develop JADC2 capabilities to meet new requirements for the Joint Force. The overall finding of the Academic Year (AY) 2022 research and field studies is that JADC2 implementation is impeded by slow JADC2 institutionalization. Despite challenges, industry partners and innovation centers are advancing new capabilities to support the emerging JADC2 market. As a result, the DoD has a unique opportunity to gain exceptional speed, creative solutions, and rapid advancement of JADC2 technology if the impediments outlined below are mitigated or resolved.

Who We Are

To conduct this study, the C4ISR Industry Study faculty assembled a team of seventeen Joint and Interagency professionals from the Army, Air Force, Marine, Navy, Space Force, National Geospatial-Intelligence Agency, Federal Bureau of Investigation, Industry Fellow from the Boeing Company, and four National Defense University staff mentors. The team members bring a combined 250 years of experience in diverse aspects of the national defense enterprise. This industry study consists of all U.S. personnel with Top Secret Sensitive Compartmentalized Intelligence access.

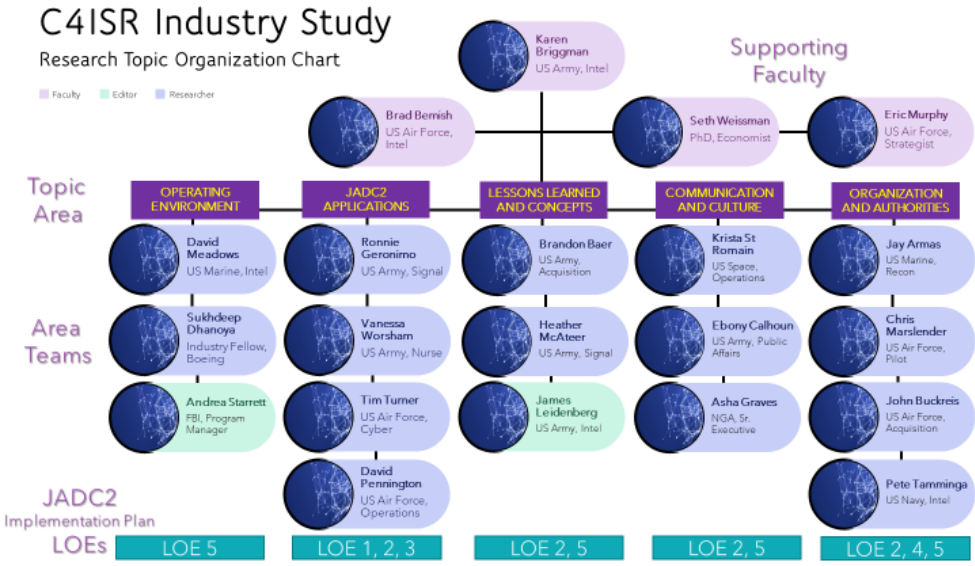


Figure 1: C4ISR Industry Study Research Organization Chart

Purpose of the Industry Study and the C4ISR Topic Area

The Eisenhower School's Industry Study Program (ISP) retains its founding purpose to remain connected with the defense industry. The ISP's prescribed intent for studies of diverse defense market segments is "to understand and assess the National Innovation and Defense Industrial Base (DIB) to effectively evaluate its potential contributions to national security." The C4ISR IS focuses exclusively on the C4ISR market and its ability to "the DoD Objectives outlined in the [NDS]."[1] Unlike other markets, the C4ISR is a composite subset of markets built around a set of integrating capabilities overlapping all other markets. This report diverges from the typical market assessment to achieve the ISP's intent while assisting leaders engaged in institutionalizing the JWC and JADC2 efforts. Within the C4ISR defense market, the IS group focused on the JADC2 efforts and the National Innovation System, and the DIB's ability and capacity to respond to emerging DoD JADC2 requirements. The previous C4ISR IS cohorts assessed JADC2 concept development. After establishing the JADC2 Cross-Functional Team (CFT) last year, this year's research, field studies, and resultant report focus on operationalizing the concepts into action and progress.

Summary of the C4ISR IS Field Studies with Industry and Partners

Problem Framing for Field Studies. The C4ISR IS team conducted a broad review of C4ISR and JADC2 literature to assess how the DIB supports JADC2 to advance national security requirements outlined in the NDS. The team built on the AY21 analysis and review of official JADC2 and related concepts documentation. The seminar discovered concerns within the DIB on JADC2's implementation due to limited JADC2 standards, understanding, and priorities. The IS team coordinated field studies with industry partners and innovation centers to understand better and evaluate the situation and offer policy recommendations.

Figure 2: C4ISR Industry Study Site Visits and Industry Engagements

Field Studies Overview. Given travel constraints and COVID-19 restrictions, the cohort conducted a mix of virtual and in-person site visits with industry, labs, and defense organizations supporting C4ISR and JADC2 efforts in addition to innovation centers and research labs. The field studies also conducted a congressional engagement with U.S. Representative Rubin Gallego.

Review of Independent Research Topic Areas. The cohort aligned their research efforts into five topic areas during the field studies and independent research. These research lines of effort include the operating environment, lessons learned and concepts, emerging applications of JADC2, communication and culture, and organizations and authorities. (See Appendix A for full details of topics supporting each focus area)

Why It Matters: JADC2 Development

What is JADC2: The Core Concept

The U.S. and its military Services are undertaking unprecedented action to achieve a continued "decision advantage" against near-term and future threats. The U.S., its allies, and its partners as decision-makers and warfighters face increasing threats from Russia, China, and a multitude of other persistent and more likely threats. The JADC2 concept seeks to achieve decision superiority, maintain geopolitical and military dominance, and prepare for various crises in a multi-domain operating environment. The U.S. requires a shift in its self-awareness, a clearer perception of its adversaries, and a more apperceptive awareness of the strategic logic that underpins the JADC2 concept. Future operations will be at a higher tempo and over greater distances than experienced since WWII. These operations include all elements of the joint force and must be time-synchronized and conducted alongside multinational partners. Adversaries will seek to disrupt and desynchronize these operations and their necessary logistics support to gain momentary advantages to exploit.

JADC2 Concept Development: Inception, Evolution, and Framework

JADC2 is "the warfighting capability to sense, make sense, and act at all levels and phases of war, across all domains, and with partners, to deliver information advantage at the speed of relevance."[2] Its roots are in Command and Control (C2), which is more than technology and is defined as "the exercise of authority and direction by a properly designated commander over assigned forces in accomplishing the mission."[3] The JADC2 concept spawned from the belief that decision timelines required modernized C2 constructs that take advantage of prolific battlefield data and technology in a near-peer conflict.[4] The Service contributions to JADC2 are the U.S. Air Force's Advanced Battle Management System (ABMS), U.S. Army's Project Convergence, U.S. Navy's Project Overmatch, and other JADC2 initiatives related to platform modernization efforts in all Services. The DoD is shifting its vision by focusing on creating a framework where its militaries are interconnected and use interoperable communication capabilities for quicker sensor-to-shooter execution, to support information advantage, and ensure assured logistics support in contested environments.

The roots and true catalyst of JADC2's development began with recapitalizing the E-8 Joint Surveillance and Target Attack Radar System (JSTARS) program.[5] Subsequently, the Air Force presented its concepts for a replacement capability, the ABMS, to the Joint Requirements Oversight Committee (JROC). While ABMS would impact the entire Joint Force, the Army and Navy also sought similar solutions in parallel.

In January 2020, the Deputy Secretary of Defense (DSD) established the JADC2 CFT to accelerate C2 capability delivery, identify materiel and non-materiel C2 gaps; provide policies, strategies, plans, requirements, experimentations, and exercises; streamline decision making and make resource recommendations; and oversee JADC2 implementation across the DoD.[6] The JADC2 CFT has established various working groups and planning teams with representatives from Combatant Commands, Office of the Secretary of Defense (Policy, Acquisition, and Sustainment, Research and Engineering), Joint Staff, and Services. The JADC2 CFT provides an existing governance structure that recognizes vertical stovepipe challenges, asserts the need to deliver capability incrementally and rapidly, and offers counter influences to traditional DoD acquisition processes. Most importantly and as depicted below in Figure 3, it makes recommendations concerning programming, resourcing, and policy to the Deputy's Management Action Group (DMAG) and capability gaps, priorities, and requirements to the JROC.[7]

The JADC2 strategy organizes around five Lines of Effort (LOEs) to guide actions in delivering JADC2 capabilities: (1) Data Enterprise; (2) Human Enterprise; (3) Technology Enterprise; (4) Integrating with Nuclear C2 and C3; and (5) Modernizing Mission Partner Information Sharing. Each LOE is guided by an Office of Primary Responsibility (OPR), who is empowered to raise issues and interact with and support the JROC through its Joint Capability Board (JCB). In March 2022, the JADC2 CFT updated the JADC2 governance details and published the JADC2 Strategy Implementation Plan.

The Joint Staff J6 JADC2 CFT has outlined software, data fabric, the warfighting network, artificial intelligence (AI), cloud, and zero trust as the enabling technologies to "sense, make sense, act at all levels and phases of war, across all domains, with partners, to deliver information advantage at the speed of relevance."[8]

The preponderance of the existing market supporting the JADC2 Implementation comes from the C4ISR market and elements within the various defense markets for current warfighting platforms in all domains that leverage communication systems and C2 capabilities.

How Industry Responds: C4ISR Industry support to JADC2 (Market Analysis)

Current C4ISR Industry Conditions

The C4ISR market is well-resourced and can integrate JADC2 requirements into existing portfolios. The DoD C4ISR budget requests are "expected to remain stable through 2026… [with] tactical collaboration and long-range targeting [as] the focus."[9] The two most recent NDS publications acknowledged and prioritized the national security risks posed by China and Russia to American domestic and global interests. Thus, the DoD is leveraging investments to modernize the Joint Force to support the Joint All-Domain Operations (JADO) warfighting concepts. Gaining and maintaining information advantage and decision dominance is vital to winning in competition. JADC2 will provide national and tactical leaders with the capacity and capabilities needed for achieving information advantage and decision dominance (Appendix F).

Defining the Purpose of the C4ISR Industry. Despite U.S. advantages across all domains, adversaries seek to exploit gaps and seams between alliances, partnerships, and domains to defeat or deny the U.S. and its partners and allies' opportunities to win in contested environments and conflicts. The C4ISR industry evolved to support understanding and enhanced decision-making as an enabler to warfighting. The C4ISR market enables the growth and expansion of JADC2 efforts. It provides industry an overall backlog baseline as JADC2 implementation efforts evolve into enduring requirements to support the DoD's force modernization.[10] Notwithstanding, the new JADC2 market has significant hurdles and challenges to becoming self-sustaining.

C4ISR in the New Information Ecosystem. The C4ISR market has evolved rapidly since the 1990s with advancements in computers, sensors, and communication transport. However, the new Information Age has entered a new phase where global influence and democratization of data makes "making sense of data" more difficult.[11] There is increased competition between nations to gain greater fidelity and understanding faster than adversaries. Information advantage can enable action advantage when it connects sensors and knowledge to shooters and influencers. As the U.S. transitions from Global War on Terror to Great Power Competition, C4ISR is evolving from ISR defense support for the Iraq and Afghanistan wars to today's efforts to make sense of it all through JADC2's integrated joint command and control.

JADC2 Market-Focused Overview

As the U.S. exited the post-9/11 conflicts in the Middle East, the overall challenge for C4ISR became creating information advantage in a contested environment in ways to generate action advantage. The central challenge is decision-making. With the rise of C4ISR data processing and management requirements, JADC2 is the foundation supporting future concept development, specifically the JWC, needed to win in a future conflict. In essence, JADC2 is the framework and fabric connecting the capabilities and platforms to deliver decision dominance.[12] The DoD's C4ISR defense industry focus has shifted from knowledge management to information management due to the growth of data and sensors.

C4ISR Industry Scope. The C4ISR industry is a composite subset of various industry markets with overlapping and interdependent areas. Complementary and independent efforts can support decision-making for the warfighter and national security professionals. One area of the C4ISR industry growth is the expansion into "C4ISR capabilities to operate in all warfare domains, including cyberspace… [and] is mature, and growth depends on the number of combat units, platforms, deployments, and scheduled system upgrades."[13] Today, the most recent FY22 budget supports "691 C4ISR programs (valued at $58.59 billion)…with planned spending [that] will be flat through 2026."[14] This growth area saw changes from the FY20 levels of "1,150 C4ISR contracts totaling $57.13 billion were awarded to 446 firms."[15] Most notably, the focus is less on sensing and more on understanding and analyzing in joint, tactical environments.[16]

JADC2-related efforts are assessed as cross-cutting $2 billion of the market within the C4ISR market area.[17] Intelligence funding added to the DoD C4ISR funding supports continued growth. JADC2 capabilities within the C4ISR industry synchronize warfighters in all environments and domains to include anti-access, area denial (A2AD) environments. The JADC2 integration gives commanders decision dominance over adversaries by connecting all

forces and all domains, providing commanders with decision options for maneuvering and supporting forces, and ensuring closure of kill chains.

C4ISR Industry and JADC2 Market Participants. The C4ISR industry is often a key business sector or unit within traditional DIB firms, such as Lockheed Martin, Boeing, Northrop Grumman, General Dynamics, Raytheon Technologies, and Leidos Holdings. These business units provide C4ISR platforms that support all modern equipment used by the DoD today, including littoral combat ships, satellites, howitzers, and fighter planes. These firms have also provided end-to-end solutions for mission command systems and battlefield awareness software for the Services and CCMDs. As the DoD moves towards open architecture and an integrated approach to connect platforms across all Services for JADC2, smaller companies and non-traditional partners have entered the C4ISR market through the support of resource definition format-agnostic Application Programming Interfaces (APIs). Smaller defense companies specializing in software like Rebellion, Anduril, and Palantir compete with Boeing, Lockheed Martin, and Raytheon in the data analytics and integration efforts. Algorithms, modality, and processing interfaces differentiate the JADC2 API development approaches,

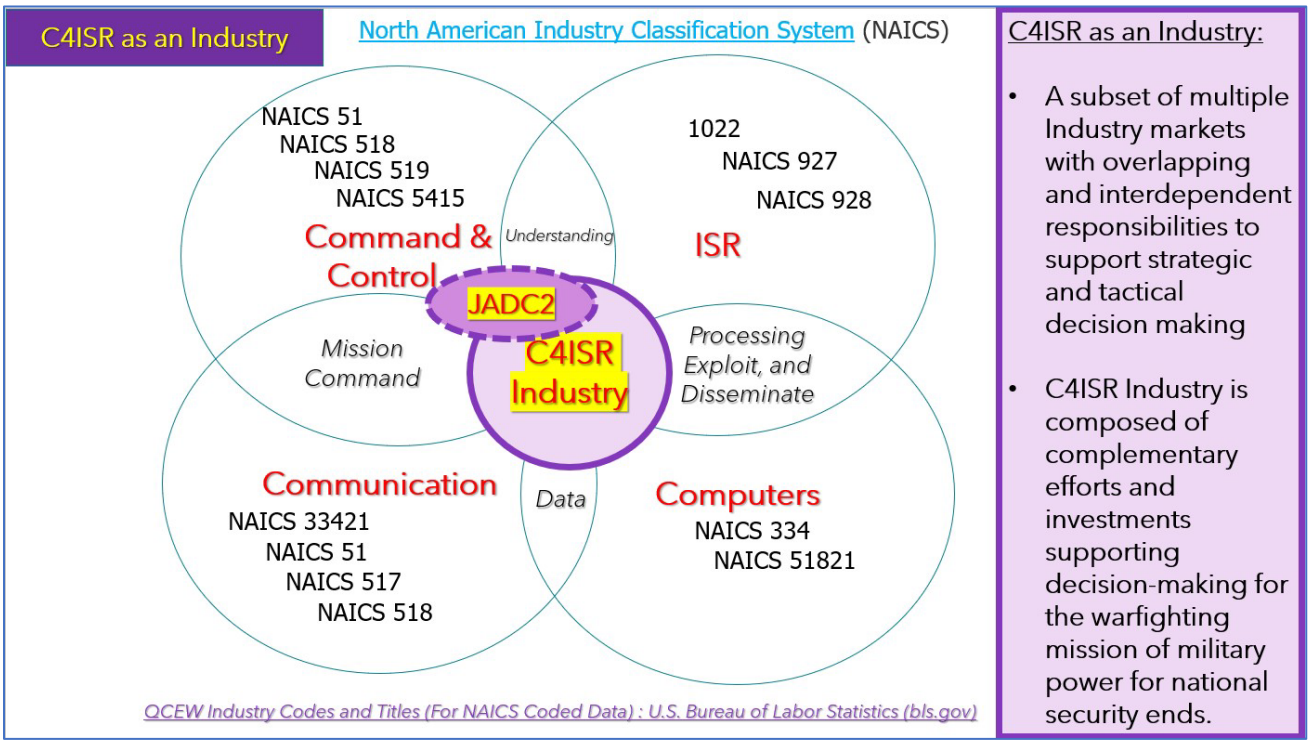


Figure 3: Defining the C4ISR and JADC2 Related Industry Classification

JADC2-Related Market Assessment

The JADC2 market is an emerging market for the larger C4ISR market with overlapping connections to many other defense markets. Market capital estimates are non-traditional because of this overlay. The IS strove to articulate that the DoD's JADC2 demand signals are not for the development of another platform or an acquisition of a single solution. It is a market to support the JADC2 mindset and concept for military operations to enable All-Domain operations, However, the concept will need enablers, and the enablers provide a business opportunity. The DoD (Services and CCMDs) and industry consulted regarding what technologies and capabilities must mature to understand the potential business opportunity. These include technology leveraged from ongoing programs in the R&D innovation centers, Independent Research and Development (IRAD) pipeline, Contract Research and Development (CRAD), or extensions of existing technology baselines that could be applied to the JADC2 problem set.

In combination with the above step, firms must conduct internal reviews of budget documents to understand what budget elements (PEs and Projects) either explicitly tied to the JADC2 problem set (ABMS and related programs in the USAF are an example of this explicit tie) or had strong implications of a JADC2 connected relationship due to either wording in the President's Budget (PB) or SME input. Industry conducts assessments over time (typically 5 years based on multiple firm input) and attributes (using things like the ABMS 6-Attributes as a guide: Secure Processing, Connectivity, Data Management, Software Applications, Effects Integration, and Sensor Integration) accordingly. This bifurcation provided firms with more than one axis to assess JADC2 market potential. Beyond the baseline PB documents, firms rely on documents and exchanges with the USAF ABMS team, Navy Project Overmatch - Distributed Maritime Operations team, and the Army Project Convergence team to inform thinking of market potential.

In reviewing the JADC2-related budget investments, the U.S. invests billions of dollars into RDT&E and procurement.[18] However, these investments are not stable and programmed. Hence, the emerging market lacks enduring budgets that create backlogs to sustain long-term investment without firms' current efforts maturing into programs or procurements.

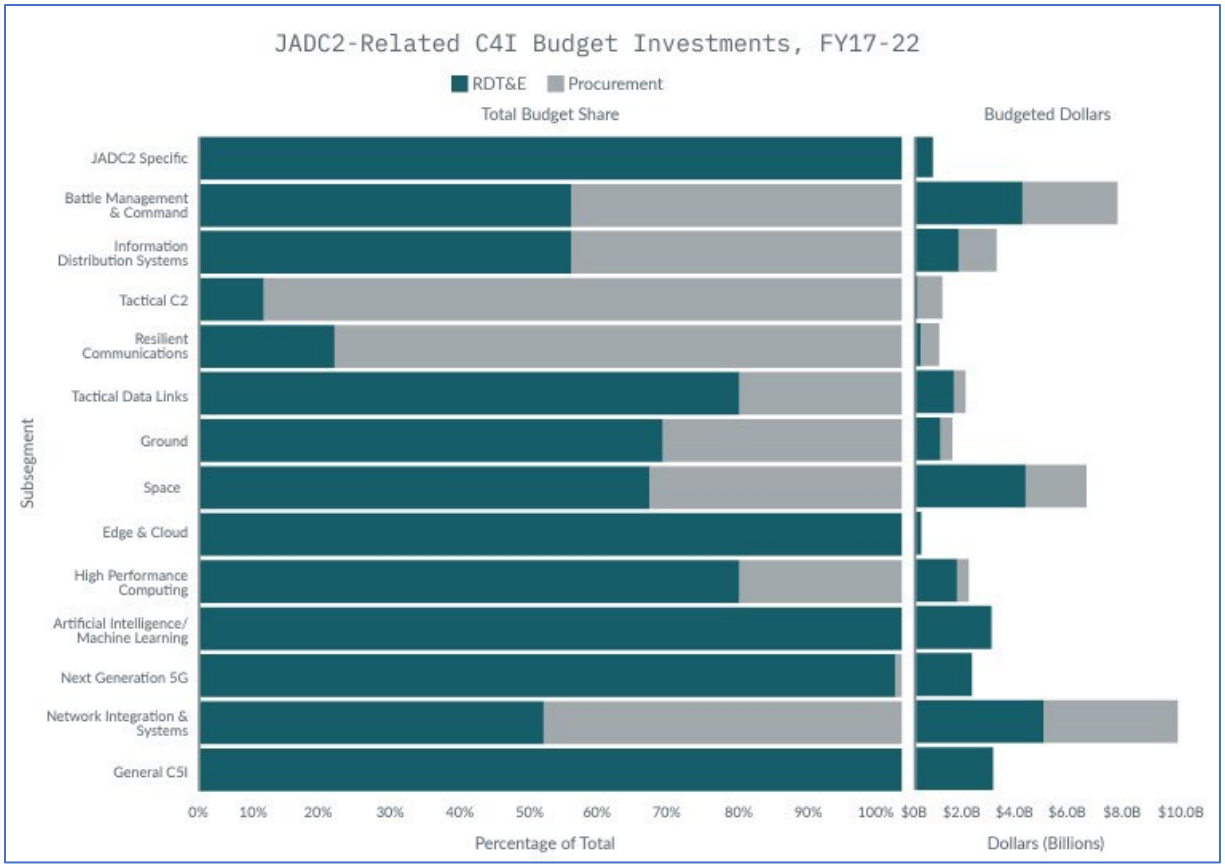


Figure 4: JADC2-Related C4I Budget Investment (source: Govini Analysis)

Industry analysis on the PB indicates that the JADC2 market to be approximately $2 billion for FY2022.[19] This is separate from RTD&E funding of roughly $5 billion. In looking at year-to-year investments in JADC2 spending, the estimates fluctuate more than in most established markets. This creates uncertainty in the industry for determining internal investments to prepare for market entry.

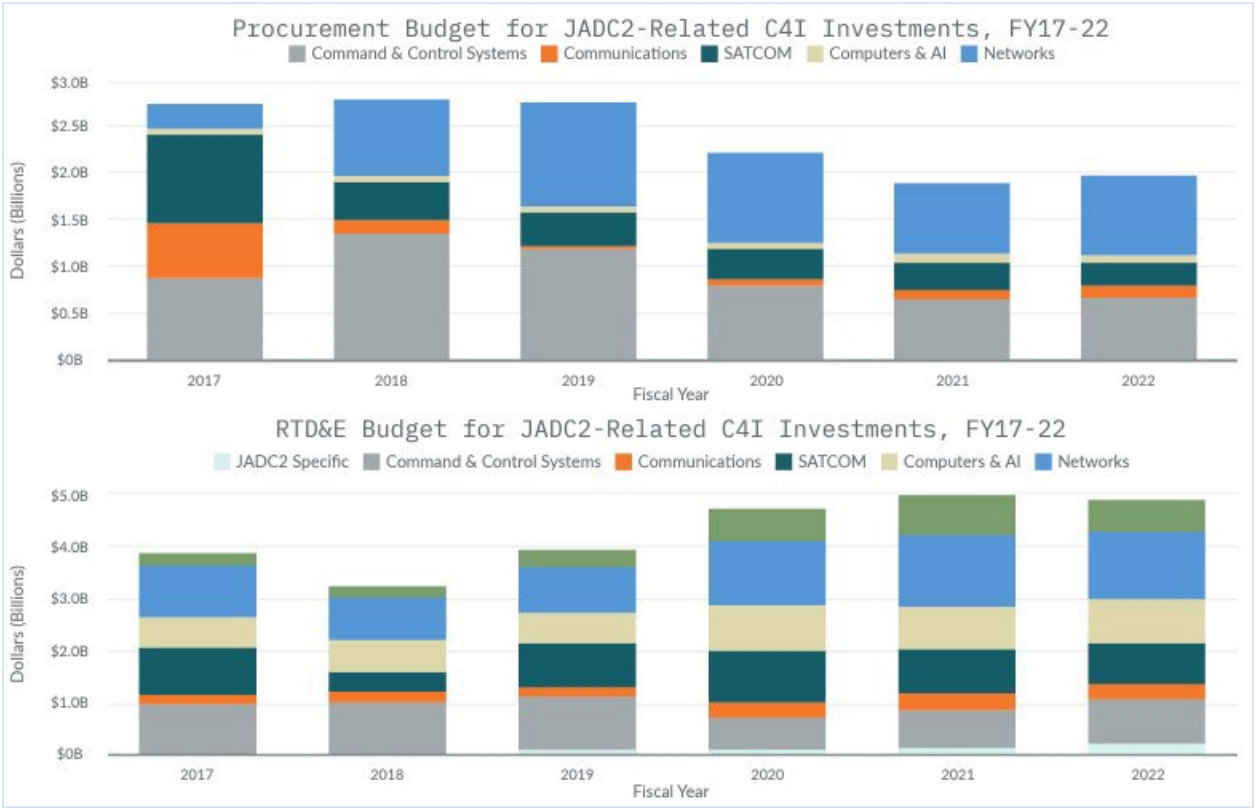


Figure 5: Procurement Budget for JADC2-Related C4I (source: Govini Analysis)

Large DIB firms assessed that success in the JADC2 market would result in success in related (more physical) defense markets. Firms anticipate growth in the new JADC2 market as requirements become more clarified and mainstream. Some firms noted a preference for more predictable and stable line-item budgeting for JADC2, similar to how the USAF's ABMS leverages current programs. They understand the challenges of advancing new innovative technologies through maturation and testing before milestone decisions but desire long-term JADC2 investments with sustained and predictable funding commitments.

C4ISR Structure Conduct Performance and Market Factor Conditions

The C4ISR market is a defense industry market with oligopolies selling to a monopsony, the U.S. government. Though there is product differentiation between the firms, the few firms which dominate as sellers in this market limit diversity of products. There are also high barriers to entry into the market, preventing the regular inclusion of new firms. Because of the limited products and monopsony buyer, the firms leverage influence over Congress, which has budget oversight of the DoD. As such, firms gain the ability to price-set their products, often passing their costs to include costs from inflation, COVID-19 mitigation, and pensions onto the monopsony buyer. The market allows for a unique competitive collaboration environment. The monopsony buyer encourages firms to team for products and to acquire or merge with one another. All of this will enable firms to be profitable while also inefficient. Quality is a concern but not overriding, allowing sub-optimal products to be obtained by the buyer. If anything, the

monopsony buyer would be concerned if a firm was not profitable and had to leave the market or close its doors.

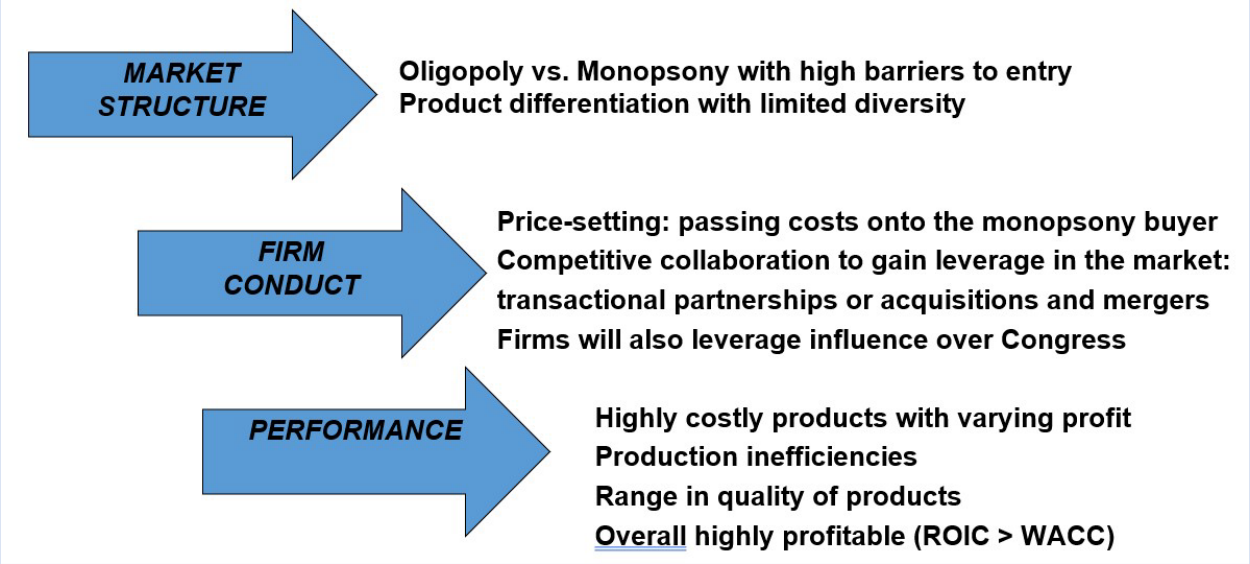


Figure 6: JADC2 Structure Conduct Performance Overview

Market Factor Conditions

The COVID-19 pandemic has impacted the market, limiting access to raw materials and the availability of crucial supply components. Production lines were either running at lower capacities or were completely shut down during portions of the pandemic. Shipping issues also interrupted the supply chain.[20]

Regulation and security concerns have also limited what materials and components can be utilized, who and what talent that industry can recruit and employ, and how business and operations must be conducted. This increases costs and creates inefficiencies. Most industry professionals indicated a concern over available labor, whether because of COVID-19, clearance capability, Science, Technology, Engineering, and Math (STEM) talent or affinity, or even lifestyle considerations. Several industry partners noted attrition issues related to lifestyle incongruence, with examples in adapting to working virtually, working with classified technologies, or supporting non-standard hours for primary caregivers. Some were also candid about a stigma associated with working for the U.S. government and the DoD in particular.

Each Service and platform have separate efforts to develop JADC2 capabilities, some of which are uniquely stove-piped. While there is an increase in R&D, some of the core sciences and technologies are being duplicated in individual efforts, as indicated by industry professionals. However, there has been increased coordination of JADC2-related efforts since establishing the JADC2 CFT.

Porter's Five Forces Analysis for JADC2

Porter's Five Forces

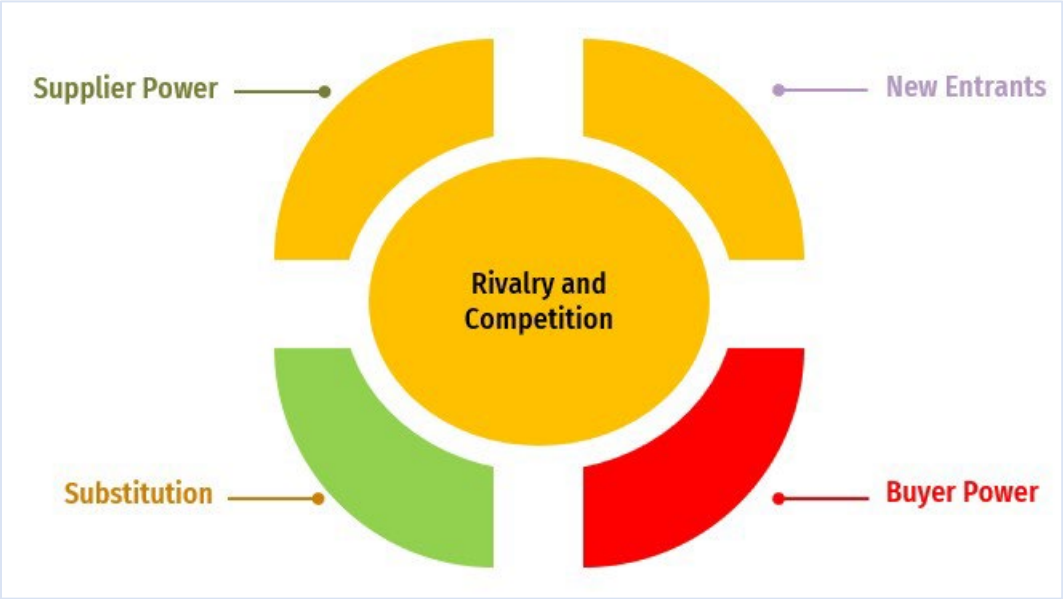


Figure 7: JADC2 Porter's Five Forces Market Assessment

Industry is energized to support the new JADC2 market by advancing new capabilities without a clear understanding of JADC2 requirements or standards. Large firms are teaming with smaller firms to bring new concepts, products, and capabilities to the market. During engagements with companies within the C4ISR industry, most outlined their approaches to carve out an enduring legacy within JADC2 in hopes of long-term profitability and national security success. However, few companies are willing to spend their own R&D funds on uncertain and ill-defined aspirations without a requisite funding commitment on the backside of these investments. The industry is guessing and positioning what they believe the DoD, the majority buyer, wants for JADC2. The JADC2 CFT has worked hard to clarify and send a clear demand signal. Still, it must address the years of changing visions and misinterpretation of current goals. Services and CCMDs have also sent their own nuanced demand signals, backed by funding for independent JADC2 initiatives. In short, supply is waiting for demand communications to align with enduring funding mechanisms before proceeding.

Rivalry and Competition (Moderate force)

While the market has large oligopolistic firms, it actively includes and incorporates small start-up companies and medium-sized firms. Additionally, companies and firms are looking to design profitable business models to support JADC2 capabilities development. Despite many competing firms, the market environment encourages collaboration and supports company teaming and prime-subprime arrangements. Thus, the rivalry and competitive forces are moderate to account for the competitive but collaborative environment.

Power of Monopsony Buyer (Strong force)

The DoD is a monopsony buyer in this defense market; however, future market growth will likely expand available buyers to include U.S. partners and allies. JADC2 is a DoD concept encompassing U.S. defense and security capabilities. Products and capabilities will evolve to support whatever the DoD indicates it wants. While the firms may be price-setters, DoD will be the product determiner. Right now, industry is waiting for clear direction based on requirements, standards, architecture determination, and funding allocation. Few firms are willing to spend their IRAD funds on unclear capabilities that may or may not progress to production.

Power of Suppliers (Moderate force)

Despite the size of the big six defense firms (and their associated leverage powers), there are aspects of the supply chain, labor, and industry restrictions (including legal, security, and policy restrictions) that they cannot control. Reflective of the broader Market Factors above, the COVID-19 pandemic has impacted the market's supply chains and pools for labor and talent. As such, materials and components are more expensive and contribute to shifting delivery schedules. There are limited options for alternate suppliers due to defense industry restrictions and globalization, and specialization of supply chains. COVID-19 mitigation measures increased costs of doing business in most markets, and JADC2 is no exception. Labor costs have increased as another supply-chain impediment impacting the broader labor market. Firms have lower incentives to utilize their full bargaining power or leverage suppliers (or employees) into lower costs since these costs are transferrable to the buyer in many cases. Thus, the power of suppliers is moderate.

Substitution (Weak force)

The JADC2 market is new and growing. No firm dominates the market, and requirements are evolving. The threat of substitutes is a weak force. There is currently no specific product or set of products to fulfill JADC2 in its entirety because it is not just a thing or product. By design of integration, openness, and interoperability, the risks of future substitution forces impacting this market are low. Future capabilities can become enhancing capabilities rather than replacements for JADC2-related products and services.

New Entrants (Moderate force)

The threat of new entrants in the JADC2 market is higher than in typical defense product markets. The DoD seeks new entrants to increase the opportunities to realize success in addressing JADC2 requirements. The Services and CCMDs have made concerted pushes for new approaches for software development and commercial innovation inclusion. These efforts create incentives for non-traditional defense firms to enter the market. Despite these incentives, vendor lock for proprietary legacy systems remains a challenge for these new entrants to integrate and connect to achieve JADC2 integration. This impediment lends to high switching and compatibility costs which protect firms supporting legacy platforms. Another impediment for new entrants is high barriers to entry created by regulatory compliance, security clearance requirements, and security costs. The threat of new entrants is a moderate force in this market.

What Slows Us Down: Obstacles to Implementation

Across the C4ISR industry, developers and managers emphasized impediments slowing or challenging their efforts to operationalize JADC2. DoD is not developing JADC2 capabilities in a traditional acquisitions process, so firms cannot rely on traditional approaches to develop products and capabilities. However, the industry remains engaged and supportive of the DoD's efforts to innovate rapidly, prototype, test, and procure JADC2 solutions. The DIB's JADC2 implementation impediments fall into five categories: (1) limitations within the DIB's operational environment and ecosystem; (2) the development of reference architecture and standards in the applications of JADC2; (3) common understanding of JWC and JADC2's concepts and approaches; (4) challenges with communication and culture; and (5) organizational design and policies supporting a unified JADC2 effort.

Limitations within the DIB's Operational Environment and Ecosystem. (see Appendix D)

The DIB and innovation centers actively develop capabilities and realign their internal processes to support JADC2 implementation. Creating cross-functional teams within private firms, investments with R&D funding in government agencies, and IRAD in DIB firms show a unified commitment to advancing JADC2. However, limitations in the operating environment beyond stable S&T investment funding impede industries' progress. The first challenge is the pace of erosion of the United States' economic and technological dominance. China and Russia have been increasing investment and revamping their military capabilities over the last two decades. According to the Interagency Task Force in Fulfillment of Executive Order 13806, "in 2001, China's annual military budget was less than $20 billion, [but] by 2017, it exceeded $150 billion, second only to the U.S."[21] The U.S. Government must increase its defense spending to invest in R&D and technology to meet the future needs of warfighters. After the Budget Control Act ended in 2021, the PB requested that Congress increase the discretionary spending limit for R&D efforts and modernization. The second challenge impeding the industry's support for JADC2 efforts is that the U.S. maintains inefficient government business and procurement practices despite acquisition reform. Services control the acquisitions and procurement, and CCMDs rely on Operations and Maintenance (O&M) funding for JADC2 efforts.

As a result, inefficiencies and unpredictable budgets impede industry action. The third challenge is the shortage of skilled labor, especially in STEM fields. For years, the United States was the world's innovation hub, with Silicon Valley leading advancements in technology. Today, adversaries like China and Russia have invested heavily in STEM talent and are exploiting America's educational institutions. China has had greater success than Russia for various reasons. According to the Interagency Task Force in Fulfillment of Executive Order 13806, the "growth in advanced science and engineering degrees shows the U.S. graduating the largest number of doctorate recipients of any individual country, but 37% were earned by temporary visa holders with nearly 25% of STEM graduates in the U.S. being Chinese nationals."[22]

Development of Reference Architecture and Standards (see Appendix E)

The JADC2 CFT continues to develop reference architecture and standards to depict JADC2's network and data infrastructure fully. However, industry and innovation centers provided common feedback that the lack of standards in data, architecture, and protocols available to them creates challenges for engineers developing solutions. DoD leaders laid out

four essential capabilities to enable all 2020 DoD Data Strategy goals.[23] The same capabilities are applicable and vital to developing a data fabric: architecture, standards, governance, and talent management. The JADC2 concept envisions all domain sensors available to all warfighters across the DoD. It provides decision-makers with the data at the speed of relevance. A data fabric is a network approach to simplify data access. This data network is Service agnostic and creates connectivity within a denied, degraded, intermittent, or limited (DDIL) environment and integrates point-to-point data interoperability capabilities. Industry is currently prototyping and developing capabilities with little understanding of the future reference architecture or standards across the Services. As a result, there is frustration with advancing capabilities without knowing whether those approaches are necessary or even usable as future standards emerge.

The DoD can examine data and deliver it on time with a common data fabric, regardless of where it resides. A data fabric will enable JADC2 by connecting sensors in air, sea, land, space, and cyberspace, interpreting the data received from those sensors, and delivering that data across an architecture in near-real time in a DDIL environment. A shared data network ensures the warfighter at the edge has the most valuable, trusted information when and where it is most useful to the mission. Dependable data standards and infrastructure that all Services subscribe to eliminate the need for approval from the chain of command to move data from one domain to another, connecting all capabilities on the battlefield. A well-connected data fabric is critical to the warfighter and commander in the field. It offers a reliable backbone for the movement of dynamic interservice data that JADC2 envisions for future conflicts.

Industry partners and innovation centers noted frustrations and additional requirements for developing operational software-based capabilities. From a JADC2 perspective, Development Security Operations (DevSecOps) provides the ability to develop, deploy, and update operational software-based capability rapidly. One technological enabler of the DevSecOps culture and practice is the platform. The platform is the "group of resources and capabilities that form a base upon which other capabilities or services are built and operated."[24] An essential nuance is that the platform provides the resources to *build* to *operate* the software; it is not simply a software development environment. The platform provides a standard configuration of software tools and services that enables the software development, testing, operations, and management without having to provide common infrastructure and services. Each Service currently utilizes multiple DevSecOps platforms that require the industry to reconfigure and redesign common software solutions.

Common Understanding of JWC and JADC2's Concepts & Approaches (see Appendix F)

Industry has a tacit understanding of the underlying rationale and intent of JADC2. Their exposure and experience come through their engagement with and product development for the Services and CCMDs. Many have developed internal models of the future operating environment that consider JADO. However, many non-traditional defense partners and small firms lack an understanding of JADC2's connection to the four JWC concepts: joint concept for information advantage (JCIA), joint concept for command and control (JCC2), joint concept for fires (JCF), and joint concept for contested logistics (JCCL).[25]

JADC2 integrates the JWC concepts into whole-of-government alignment in support of strategic, conventional, and irregular forces: All-Domain, offensive, defensive, kinetic, and non-kinetic.[26] Service integration has been primarily informal to this stage of JADC2 development.

Though several letters of agreement (LOA) exist to drive interoperability, JADC2 CFT lacks the authority and resources to integrate efforts and cannot mandate integration. Though the CFT released a strategy in the fall of 2021 and an implenetation plan in early 2022 that provided a strategic vision for joint progress, it still lacks connection to specific and actionable plans with tangible deliverables. Services offered existing efforts as demonstrations of progress, but efforts were not directly and deliberately aligned. Notably, Services have similar challenges aligning their internal JADC2 efforts,

The Joint Staff and Services have not yet decided on the appropriate level of requisite Service integration. The integratory pursuits of JADC2 should extend beyond data infusion to output similarities. Industry offered that the answer must strike a balance between flexibility and interoperability. Answers to these questions will help industry narrow the framework ambiguity, and officials should address them before devoting significant resources to an integrated joint solution.

Challenges with Communication and Culture (see Appendix G)

In 2020, the DoD released the JADC2 Vision, followed by the Strategy and Implementation Plan in 2022. These documents intended to clarify the definition of JADC2, introducing it as a concept that undergirds the way the force operates in an "increasingly information-focused warfighting environment."[27] The public release of this strategy raised more questions than it answered.[28] Touchpoints with industry, academia, and defense organizations revealed that stakeholders within and outside the DoD still struggle with a shared understanding of what the Department is trying to achieve. Communicating through change is difficult regardless of the size of an organization. It is often difficult to strike the right balance between the natural uncertainties of “newness” without compromising the idea's credibility or that of the organization. For the DoD, this task becomes more difficult given the overarching defense culture and the exacting expectations of the external stakeholders who influence the process of change. To develop the lexicon and unity of effort needed to bring JADC2 into fruition, the DoD must overcome critical communication gaps.

In dialogue with other IS seminars, innovation centers, representatives from various Services briefing their efforts on JADC2, and industry partners, the IS assessed the accepted meaning and purpose of JADC2 remains unclear. SMEs from industry and innovation centers with portfolios supporting JADC2 explained it as a concept or platform in ways inconsistent with the JADC2 CFT’s larger vision. As a general observation, these personnel expressed mixed opinions about its potential and likelihood of success, which reflects concerns in the larger DIB ecosystem.[29] However, when asking these developers what the DoD needed to do in future conflicts where information is more prolific and adversaries operate with greater agility, their recommendations remained consistent with and, in most cases, already incorporated into the JADC2 strategy. JADC2 is not just a framework, integrating activity, or concept. It is not just a platform or a component resourced in a program of record. It is also a cultural mindset that accounts for a sense, make sense, and act approach in every resourcing and warfighting decision. The JADC2 Implementation Plan outlines a basic education strategy under human capital LOE 2 to strengthen data and analytical skills, build trust in human-machine teaming, and make decisions that impede the adversary’s kill chain. However, a basic plan is not enough at the stage when institutionalization of core concepts must keep pace with technology. While not a policy recommendation, immediate implementation of robust JADC2 education and training is essential

to reinforce a dynamic communication strategy necessary for a cultural evolution that embraces a JADC2 mindset in every tactical, operational, strategic, and resourcing decision.

Without education and training at all levels, communication alone will not have a lasting cultural impact. Instead, equitable stakeholders across DoD, Congress, IC, international, commercial and defense industry, and academia will continue focusing on differing interpretations or the lack of updated doctrine, policies, and authorities rather than acknowledging what is already being done or could be done with industry to meet senior leader intent. JADC2 capabilities are already being explored and operationalized. While numerous expert panels and video clips highlight JADC2 progress or concerns, few individuals or organizations are exposed to this information. To accelerate policy and authority development and acceptance, exposure to a common JADC2 educational program will drive a JADC2 mindset that focuses on information sharing, integration, and interconnectedness across all stakeholders.

Enduring Challenges to Overcome Diversity, Equity, and Inclusion Hurdles. Promoting diversity and establishing inclusion and equity in policy is imperative to creating a more capable force that reflects society.[30] Meaningful changes will not occur without leveraging everyone's full potential. Diversity, Equity, and Inclusion (DEI) programs and activities to promote these efforts exist in almost all firms. As with many STEM-reliant markets, the firms acknowledged the hurdles and challenges that accounted for their underrepresentation of minorities and women. JADC2 is an emerging market seeking to bridge the diversity in systems, data, architecture, relationships, and people. The success of both DEI and JADC2 programs requires proactive actions to ensure stakeholders are represented and integrated. There is an opportunity to utilize JADC2 implementation to institutionalize and promote diversity to drive opportunities in underrepresented technical fields. Firms and innovation centers acknowledged that JADC2 investments provide an opportunity to increase the inclusivity of all stakeholders and a visible representation of race, color, and gender as the new industry emerges. Multiple large DIB firms have already adopted DEI policies to promote diversity and take action to partner with Historic Black Colleges and Universities (HBCUs) and minority-owned companies.

Policies and Organizational Design Supporting a Unified JADC2 Effort (see Appendix H)

JADC2-supporting firms and innovation centers noted the overlapping nature of JADC2 efforts resourced by different Services and CCMDs. In fact, many firms established internal cross-functional teams of their own to coordinate and integrate their efforts across business units, segments, and programs to achieve internal standardization and interoperability. However, they expressed concern that it may be premature to advance a single cross-industry and cross-Service standard. They recommended greater synchronization and coordination that they did not see as existing. They also believed that JADC2 efforts lacked a DoD-wide coordination element as a central point of contact to ensure viability and appropriateness of solutions across the Joint Force. The JADC2 CFT serves as an integration committee between the Services' efforts. However, it does so with no authority over the Services' program offices and limited resources to enforce standards and fully coordinate integration of all JADC2-supporting programs. Services are also struggling to achieve a similar level of internal integration.

As a result, the JADC2 CFT is pursuing program integration but can only progress at the Services' commensurate ability and speed of willingness for participation and burden-sharing. The JADC2 strategy specifies goals and LOEs to connect Service pursuits with larger joint endeavors. Meanwhile, the Services are progressing along different paths. In an unclassified realm, the Navy's Overmatch remains a largely stove-piped effort, albeit a very successful one making significant progress. It is understandable that many view maritime domain programs with skepticism about their interoperability across the classified spectrum for additional information pooling. The Navy is working to bridge Joint Force-wide gaps in interoperability by developing and testing capabilities alongside Joint and multinational partners. Project Convergence has provided culturally innovative opportunities to experiment and learn while leveraging CFTs to solidify progress into action. Nevertheless, the endeavor's results are difficult to scale for operational use appropriately. The Air Force's ABMS appears to be the most advanced and best-resourced effort, though, to be fair, it also has the most extended history. However, it remains focused on the air domain centricity and centralized nodes of information passage which are less congruent with the other Services. The JADC2 CFT's steepest challenge is balancing integration requirements to facilitate Service collaboration without stifling innovation and progress.

How We Get There: Fully Resourced Policy Recommendations

The following section offers recommendations for DoD leaders to institutionalize recent advancements in JADC2 implementation to assist healthy growth of the JADC2 market. Some recommendations extend beyond the C4ISR market but will enable clear engagement with industry on JADC2 efforts

Recommendation for the DoD

Institutionalizing Joint Standards

Create a Common Strategic Scenarios Set for Capabilities Development. Industry lacks a clear and consistent understanding of the strategic logic driving the perceptions of adversaries. Firms have developed their own internal threat scenarios and future environment descriptions to build out capabilities within their market segments assessed as supporting JADC2 efforts. The DoD could create simulation tools reflective of the threat environment to test and develop capabilities that directly support its long-term strategy. Simulation tools and scenarios assist industry innovators and avoid wasted efforts on ill-designed solutions. A more precise depiction of adversaries, awareness of the strategic logic that underpins the JADC2 concept to achieve decision-advantage, and tools to replicate a multitude of various crises in an All-Domain operating environment will enable greater focus on the strategic hurdles JADC2 must overcome in a DDIL environment. Investing and developing solutions without appreciating these challenges could result in failed joint integration efforts that inadequately support potential conflict with a peer or technologically advanced adversary. Without focus and direction, a reactionary and hectic engine of progress may prevent the thoughtful and more constructive actions needed to achieve the most significant technological advancements required for any revolution in military affairs.

Leverage Iterative, Agile Design with Prudent Risk. JADC2 development requires the DoD to become less risk-averse: prepare to fail quickly, accept partial solutions or capabilities, and move rapidly to the next project in search of solutions and improvements. Agile, iterative processes for JADC2 development may require updated policies outside a requirements-based system. JADC2 capabilities will require design and interface changes in diverse environments, making achieving a perfect final deliverable impossible. Iteration allows hardware and software capabilities required for JADC2 to get into the field faster, where lessons can be applied to drive refinement and product updates in near real-time. The JADC2 concept also requires integrating and fusing data from multiple sources that change dynamically. Separate companies can build these solutions. The DoD's push for an open mission architecture and development framework will ensure interoperability; however, the Joint Staff and the Services can only institutionalize these solutions through the acquisition process that supports funding and procurement of systems. R&D and O&M funding cannot become the primary vehicle for interim solutions. Interim solutions allow for on-the-spot technological changes and adaptations, but they still require total funding and procurement that ensure a steady income for firms.

Create Common Data Standards and Leverage Containerization. The DoD must release common data standards to ensure that data created from disparate sources can be aggregated together. This effort is underway; however, it too must be iterative to allow for advances in technology. JADC2 development will never be complete, and the fielded version will emerge different from today's vision. This will help inculcate a mindset shift of constant development, revalidation, and advancement as the goal of any program. Industry demonstrated agile software design methodology in action. Specifically, using containerization of software allowed secure updates and continuous product improvement. Of note, containerization is an emerging approach that delivers agile products to the market without the risk of security vulnerabilities. This approach is different from current practices of system administrators updating software or software packages in individual systems in the network.

Establish an Industry Consortium for Joint Data Fabric Standards. A common data fabric is a must-have for JADC2 to materialize. While technology is essential, creating more technological solutions without a common transport mechanism for streamlined access between siloed military branches and networks will not succeed. First, the C4ISR industry will have to enable the data fabric architecture with technologies that allow data to move rapidly.[31] These industry leaders could be fully federated into a consortium and be responsible for informing DoD policy for an interconnected backbone (peer-to-peer) and the internal networks and maintaining security as the priority within the network. This consortium approach is a common practice used by telecom and global web services providers for standardization. These partners would assist with developing procedures and protocols to maintain Zero-Trust Architecture (ZTA) standards. Next, the DoD should employ standards for managing and utilizing the data fabric.[32] These standards should apply to application programming interfaces, data labels, and data tagging relating to sharing data across domains and Services. Finally, DoD data fabric governance must provide the principles, policies, processes, and frameworks to effectively manage data at all levels.[33] DoD leaders must assign ownership with a specific vision, focus areas to ensure sustainment of the data fabric, and responsibility for data to pursue interoperability to advance JADC2.

Create a Common DevSecOps Platform with Industry Input. Disaggregated C2 in a DDIL environment is critical to the JADC2 strategy. A common DevSecOps platform best enables C2 Application portability with additional benefits in resiliency, security and monitoring, cost efficiencies, and lower JADC2 barriers to entry for industry and academia. The major challenge to an enterprise platform approach is the PPBE process and associated stovepipes. The DoD primarily acquires capabilities through acquisition program offices. Both the organizational structures and budgeting processes encourage vertical stovepipes within programs and create barriers to horizontal integration. The JADC2 CFT was initiated with full recognition of these factors. Its existing governance and access to DoD decision-making bodies provide avenues to drive decisions related to DevSecOps platforms. A common DevSecOps platform maximizes application portability and minimizes the time and cost required to integrate new applications across "devices." The flexibility commercial users have today with their smartphones provides an example of how smartphone providers develop and update the underlying device. The application provider needs only concentrate on their software. A common platform also improves C2 Application portability across multiple security levels, a critical need within JADC2.[34] JADC2 C2 Applications must run at multiple security levels, regardless of the system's classification on which they were developed. A common platform provides a consistent set of tools that ensures application portability across networks.

Normalize Open Architecture Acquisition. To advance JADC2 capabilities, the DoD must acquire more open architecture systems that operationally align JADC2 efforts within the Joint Force and close the gaps with intellectual property (IP) between industry and government. DoD and industry leaders must find a way for systems to communicate in a way that remains profitable for industry partners. Future systems must include interoperability and integration within their baseline design. Like the DevSecOps methodology, building open architecture systems with data interoperability is crucial to connecting sensors to shooters on the battlefield. As mission commanders communicate their requirements, they must be careful to design less proprietary, closed, contractor-owned systems and shift to more standards-driven, open, and government-owned systems to facilitate interoperability. The DoD must incentivize the C4ISR industry to move from integrating independently of the DoD and prioritizing its proprietary systems. Moving to a more open, government-owned system architecture requires contractors to deliver systems that integrate into the current environment, fostering healthy competition, and helping to maintain a healthy industrial base. Platform-supporting software should remain open and independent of the platform. The 2020 Software Modernization Strategy is a good starting point as most solutions to advance JADC2 will be software-based solutions. More specifically, the third goal in the strategy requires customers to pursue modular open systems approaches that ensure flexibility and agility in creating mutually beneficial business arrangements that recognize and distinguish DoD's roles as customer, co-investor, and co-developer.[35] In essence, the industrial base should develop systems and software *with* mission owners instead of only *for* the mission owner, encouraging more agile acquisition processes.

Institutionalizing JADC2 with Supporting Policies and Processes

Update the DoD Policy for IP Protection. Due to the nature of JADC2 development, IP management will ensure the DoD can maximize investments that enable interoperability and open architecture. The JADC2 CFT should advocate for more formal IP management as offered by recent GAO findings on IP management. The 2021 GAO report recommended that the DoD gain control of the growing threat to IP. The four recommendations are (1) institutionalize DoD

IP Management; (2) establish a federated cadre to oversee IP management in the OSD; (3) IP cadre collaborate with Defense Acquisition University (DAU) to ensure acquisitions officials conform to IP management standards; and (4) the Director of the IP Cadre establishes IP management credentialling for key personnel.

The first recommendation to consider is action by the Under Secretary of Defense for Acquisition and Sustainment to ensure that DoD's planned guidebook on IP clarifies how DoD personnel can pursue detailed manufacturing or process data.[36] Second, the Secretary of Defense should determine the collaboration, staffing, and resources needed within the Office of the Secretary of Defense and across the components to execute DoD's proposed federated approach for the IP Cadre.[37] Third, the Assistant Secretary of Defense for Acquisition should ensure that the Director of the IP Cadre collaborates with the President of DAU to prioritize IP-related tasks that DAU should undertake between 2023 through 2025.[38] Finally, the Assistant Secretary of Defense for Acquisition should ensure that the Director of the IP Cadre develops additional guidance to help component heads and Defense Acquisition Capability Managers (DACMs) identify the DoD personnel in key career fields that would benefit most from receiving IP training and credentials.[39]

These recommendations address major congressional concerns about how the DoD manages IP. By tapping into a larger pool of IP experts to support program offices, DoD can develop new IP strategies for negotiating with defense industry contractors. The newly recommended processes will analyze program valuation strategies across the DoD and incorporate effective processes and procedures into department-wide guidance. In addition to examining strategies for acquisition programs, the DoD must also ensure it underscores the importance of licensing and acquiring IP early in the acquisition process and define the Department's instructions and guidance for obtaining detailed manufacturing or process data. These actions would need to be coupled with new acquisition processes and proper operational alignment.

Continue Moving from Platform-Centric to Data-Centric Capabilities Development. The DoD should continue its move away from platform-centric to data-centric capabilities development for JADC2 efforts. Weaponizing data through JADC2 to gain information advantage provides commanders with more time-sensitive options and decision advantage. Traditional development of C2 and data-analysis solutions built as an integrated subset of a platform create backend integration issues for connecting platforms as an afterthought. Data-centric capabilities development independent of platforms can achieve JADC2 integration and adapt in the future to incorporate evolving JADC2 capabilities that enable the platform to gain more optimal performance, even without upgrades or modernization. However, the private sector non-traditional firms lead data-centric capabilities development of new and more effective algorithms, processing methods, and decision interfaces. A key area of such development is happening in AI and computing innovation in the private sector. Developing independent of the platform enables small business teams within acquisitions process to assist non-traditional companies understand the data requirements and recruit them to find the best solutions. This will help lower barriers to entry for smaller companies to gain government contracts.

Coordinate Prioritization of Investments and Resourcing of JADC2 Efforts. The Services control acquisition and prioritize efforts they assess as most essential to support CCMDs. This reality does not preclude Joint Staff efforts to align investments and procurement across Services in support of the DSD. However, it requires mechanisms to achieve collective understanding and synchronization. The JADC2 CFT has attempted to align these endeavors with the establishment of the JADC2 Implementation Plan. But there are other ways to synchronize further long-term investments and develop enduring solutions for JADC2.

First, Joint Staff awareness of JADC2 efforts within the Services and CCMDs is critical. Second, with DSD guidance on the level of investment into JADC2, the J8 officials must pursue total funding requests for individual Services' pursuits of their JADC2 solutions. Funding allocation to these programs is the DoD's investment in supporting JADC2 development that keeps the industry committed to the JADC2 market. Piecemeal or disaggregated funding may have inadvertent impacts on industry progress since investments are cross-Service and platform. JADC2 CFT must clearly define reporting requirements to ensure the J8 can account for interrelated Service spending requests that yield the total funding requests for prioritized efforts. Third, the CFT should coordinate LOAs that articulate the process and frequency of Service communication. The program products do not have to have JADC2 integration fully solved; however, the developers must convene during development to identify simple avenues or opportunities for integration. Fourth, the phases described above need dependable funding, and the mature endeavors need immediate funding. This will enable actionable progress and attract industry to follow suit. The division into smaller programs with agility to coordinate across programs while developing solutions will also entice competition and reduce deterrents to smaller companies.

Develop a JADC2 Mission Partner Engagement Strategy. JADC2 framework is materializing into action in industry within the U.S. and among partners. Industry noted the need to develop a long-term strategy for delivering capabilities to mission partners. Several firms reported the challenges in navigating the caveats and restrictions with information sharing and technology transfers to mission partners. The Ukraine-Russo Crisis highlights the importance of beginning the process of sharing data across multinational and coalition teams. Several firms also noted that U.S. partners and allies are making significant JADC2-like programs and investments. In JADC2, the algorithms and analytic approaches to sense, make sense, and act are more important than the underlying data. Some mission partners may lack the advanced sensors and platforms to provide robust data, but they may have cutting-edge JADC2 solutions that could support the Joint Force JADC2 efforts. The JADC2 CFT's LOE 5 efforts support the CCMDs integration with multinational partners.

Initiatives such as the Mission Data Platform (MDP) developed by the INDOPACOM J6 has made it possible to navigate through 32 episodic mission networks in the theater through a classification and network agnostic platform and has flattened how data is passed across joint and mission partners in the region. In addition, their Mission Data Platform delivers a common operating picture across all domains making it possible for our mission partners to view the operating environment as we do. This bottom-up innovation at INDOPACOM provides options in towards a solution to JADC2 LOE 5.

A JADC2 mission partner strategy and framework will enable CCMDs to develop solutions that support global integration operations across CCMDs. The mission partner

engagement strategy can also support coherent communications with partners on JADC2 requirements. A mission partner strategy will support mission partner technology integration combined with efforts supporting information sharing and C2 collaboration. The DoD needs to align their internal and external communications and align funding towards current JADC2 implementation with mission partners, so they make the right investments now.

Institutionalizing a JADC2 Culture and Mindset

Enable End-User Innovation Through DoD JADC2 Innovation Outreach. To leverage STEM talent within the DoD, organizations within the DoD have launched a series of defense innovation contests. Such competitions for JADC2 efforts will help advance JADC2 incorporation into a larger array of warfighting areas more quickly. Users with skills and understanding of emerging toolsets may provide internally developed solutions that could drive further innovation and requirements. These contests offer start-ups, consortia, and individuals opportunities to showcase unique ideas, hoping that their invention earns investment from the DoD. Competitions such as the XVIII Airborne Corps' Dragon's Lair and the Air Force Spark Tank focus on searching for the hidden talent inside the DoD to identify tech solutions for a myriad of challenges across the force.

These are bottom-up solutions driven by and designed by the Servicemembers and civilians across the force. For the last several years, the Service competitions reached across their population to present ideas. In other words, contests sponsored by the Army were only open to the Army. Air Force contests applied solely to the Air Force. However, several programs recently opened solicitations for participation to members of the Joint community, inter-agencies, and international partners. In March 2022, the Dragon's Lair opened their competition to incorporate members from all Services and limited mission partners to cross-pollinate ideas that had applications throughout the force. By federating innovation programs like the Dragon's Lair, Services attempt to break the interservice silos and move towards the true spirit of joint integration. These Joint programs widen the talent aperture, allowing innovators to explore single tech solutions that may have multiple applications across the DoD. While these programs are delivering novel tech solutions, they have the potential to provide the Department with valuable opportunities to bridge communication challenges, as well. Innovation labs can also identify influencers at echelon who can help scope the language that bridges both the generational and interservice divides.

Develop Backwards Plans for JADC2 Communication Efforts as a Methodology. The DoD backward-plans operations but forward-plans public communication and engagement. The Amazon Working Backward approach suggests developing communication in tandem with the development of an operational concept. By working from the view of the finished experience instead of working towards an idea, Amazon leaders build the language they want their team to coalesce around before launch and provide an anchor point to move from concept to delivering critical outcomes.[40] Developing a shared view of the DoD "customer" experience keeps the Department, and its stakeholders focused on the solution's utility. Iterating on the narrative of the experience throughout the critical stages of implementation helps refine the language of change while maintaining focus on outcomes.

Curating the right mix of influencers across the force provides the DoD with multiple engagement opportunities that could prove fruitful as the JADC2 framework matures. Creating feedback touchpoints between the JADC2 CFT and these influencers could help refine the

lexicon used at critical points during concept implementation. This input should help unify the language used to external and internal audiences. Developing an internship or seminar series between influencers and the Defense Innovation Board could serve as an opportunity to create a cohort of junior leaders who are informed and endorsed to help senior leaders extend their reach to audiences that they cannot engage directly. These audiences include academia, local innovators, and other hidden talents across the force.

Create an Engaging Two-Way Communication Plan. JADC2 needs to create a balance of fair and open opportunities and competition between big industries, small businesses, and non-traditional vendors. The DoD must continue to extend outreach efforts toward small businesses and non-traditional vendors to maximize access to innovation and new technologies. The DoD must provide consistent messaging to industry to allow easy access to the right people and organizations for JADC2 engagements with each Service. The Army alone has eight unique cross-functional teams, each working on various priorities and balancing relationships with their supporting acquisition organization. Lack of consistent messaging leads to confusion regarding roles, responsibilities, and injection points for industry to engage.

Implement a JADC2 Education Strategy Now – Operator to Senior Leader. Addressing resourcing requirements with industry necessitates understanding the capabilities needed for success. Therefore, education must begin at commissioning sources and technical schools and continue in all phases of Professional Military Education (PME), including the general and flag officer ranks (GOFO). The following actions are recommended to support this multi-tiered approach. The JADC2 CFT recognizes JADC2 education as a necessary component of the JADC2 Implementation Plan. The Joint Staff already directed the National Defense University to begin JADC2 training in the next academic year. However, further reaching options may institutionalize JADC2 into the larger Joint Force.

First, the Joint Staff should prioritize Joint Roadshows that present all Service contributions, the JADC2 strategy and intent, the Joint Warfighting Concept, Congressional concerns, and industry and academia efforts The audience is military educational institutions across the Services. Second, infuse command and control objectives from the Air Force's recently canceled multi-domain officer career field into academy military strategies courses, not just PME.[41] Third, conduct joint Service academy exercises to elevate the importance of information sharing in data-driven decisions; exercises will incorporate lessons and participants from civilian national security academia programs. Fourth, mandate data fluency education utilizing industry standards like those found in Udemy Digital Academy, DataCamp, or Amazon Web Services free digital programs. Finally, incorporate defense industry R&D and JADC2 visions into GOFO courses.

Computer-based training (CBT) is essential to normalize JADC2 across the force to solidify a common understanding. CBTs should provide the same information as the Joint Roadshows. Required data fluency programs should complement internships at industry, commercial, and R&D institutions. A partnership with Hollywood's MasterClass should be investigated to provide state-of-the-art JADC2 instruction led by current and past influential leaders across the national security enterprise to reinforce DoD intent.[42] Once implemented, these recommendations can be disseminated to all stakeholders to instill and institutionalize a common JADC2 mindset that ensures JADC2 is at the forefront of any resourcing or requirements discussion. All will better understand what is being done and what is still needed.

Leverage JADC2 Investments to Engrain Diversity, Equity, and Inclusion. The DoD can leverage JADC2 investments and implementation to foster relationships and career enhancement for businesses and individuals representing diverse backgrounds, experiences, skills, technology proficiency, and capabilities. Additionally, the DoD can also incentivize defense industry to increase diversity representation in JADC2-supported partnerships with minority and women-owned businesses as well as filling professional positions. These efforts are widely supported and ongoing in many firms supporting the JADC2 market. JADC2 stakeholders can foster inclusion and promote diversity's benefits to modernizing defense capabilities and advancing emerging technologies. This emerging market offers a unique opportunity to institutionalize the DEI efforts in the JADC2 market ecosystem.

Recommendations for Industry Partners and Future C4ISR Market Participants

Institutionalizing Joint Standards

Facilitate Innovation to Drive New Requirements. Project Maven demonstrated the transition of the formal Cold War-era idea that major defense-related technologies are built by the government and then shared with the commercial sector. Industry is developing innovative technology iteratively with better innovative solutions that mature into new requirements. Some of the technology needed does not reside within the DIB. As highlighted in the 2020 Congressional Research Service review for AI and National Security, AI technologies present a challenge for military integration as most of its development is happening in the commercial sector. In JADC2, the DoD will require input from the defense and commercial sector industry to inform requirements and potential use-cases for emerging capabilities. Globally, the AI market is expected to grow by 19.6% in 2022.[43]

Collaborate and Support DoD Common Data Standards and Frameworks. Competition and collaboration in JADC2 product development is the greatest way to deliver the best solutions for national security. Each advance opens new possibilities. A common baseline of standards and frameworks increases the potential opportunities for market participants and creates a predictable development environment. Companies need to be prepared to develop software using a common framework and comply with common data standards. Creating and using open-source code and processes, learning JADC2 standards, and bridging legacy and future platforms to support the published standards will increase companies' ability to integrate warfighting capabilities.

Work with the DoD to Develop a Common DevSecOps Platform. Industry should communicate the requirements for an optimal DevSecOps platform through their current portfolios. Companies need to be prepared to develop software using a common framework and comply with common data standards. Firms must be collaborative and prepared to work alongside each other as they share pieces of major government weapon systems constructed from several companies' software and applications running on a common enclave.

Institutionalizing JADC2 with Supporting Policies and Processes

Develop Partnerships with DoD Labs. Industry leaders must connect their efforts with DoD's strategic goals for JADC2 by directly working with independent research capabilities whenever possible. An example of this partnership is a cooperation between legacy systems software designers and innovation center research efforts into JADC2 product development. New DoD Intellectual Property management practices and open architecture systems should reduce impediments to cooperation. The Federally Funded Research and Development Centers (FFRDC) networks, like MIT Lincoln Labs and the MITRE Corporation, and University of Advanced Research Centers (UARC), like the University of Texas Austin, can offer a pipeline for technology maturation. Officials should also pursue IRAD efforts with corporate portfolio leading partners. Empowerment or incentivization may effectively offshore much of the requisite research and development to recognize concept development opportunities ready for immediate progress capabilities. Partnering efforts allow firms to focus on rapidly developing solutions from these opportunities. This connection can take different forms, but it must be substantive and collaborative.

Foster Partnership and Collaboration between Small and Large Firms. The DoD will need to work with the commercial industry to remain abreast of these developments. Adversaries are leveraging state-owned enterprises with dual-use mandates to foster their innovation. The DoD must partner with all segments of emerging technology markets to prevent adversarial advantages and maximize the potential of the U.S. market to meet national defense requirements. For many small companies which are leaders in their fields, the barriers to entry on a government contract can appear out of reach. Large firms can collaborate with smaller firms to bridge these barriers. In some cases, large DIB firms are already supporting efforts to bridge the gap for small firms.

Institutionalizing a JADC2 Culture and Mindset

Leverage JADC2 Investments to Engrain Diversity, Equity, and Inclusion. Firms can leverage JADC2 investments and implementation to foster relationships and career enhancement for businesses and individuals representing diverse backgrounds, experiences, skills, technology proficiency, and capabilities. This emerging market offers a unique opportunity to institutionalize the DEI efforts in the emerging JADC2 market ecosystem. Firms should continue outreach to train and recruit a representative workforce and partner with organizations like HBCUs and minority-owned and women-owned businesses. JADC2 offers an opportunity to overcome historic challenges with underrepresentation in STEM and promote DEI.

Friction Points and Areas of Future Consideration.

What Organization or Headquarters Leads the JADC2 Effort. Multiple agencies and industry partners stated that JADC2 needs a Joint enforcement element and unifying authority. Representatives from the Navy, Marine Corps, Air Force, Space Force, and Army elements at the innovation centers and labs mostly agreed. Without leadership, those in favor of a Joint enforcement mechanisms argue that many efforts are wasted and duplicated. One representative even stated that the DoD should not invest in JADC2 technologies for "experimentation and exercises until all the Services are doing it together." The primary argument for Joint enforcement is that policy must align with the JADC2 framework. While the 2020 DoD Data Strategy provides some vision, focus areas, guiding principles, essential capabilities, and goals, it

does not assign specific authorities to a DoD entity, failing to designate ownership and responsibility to such an entity to pursue data interoperability. To advance JADC2, the Joint enforcement element must have ownership of the concept.

Regarding ownership of the operational aspects of JADC2, two recommendations are: (1) Since JADC2 will involve operations, transition ownership to the within the Joint Staff J3 Operations or within a future global integrated command structure with responsibility for global integration; or (2) Ownership under the current alignment, assessing that the expertise and delegated authority required resides in the J6. The DSD tasked the JADC2 CFT to function as the integrating element on the Joint Staff to facilitate DoD decision-making pertaining to JADC2 but not dictate to Service actions that are inherently theirs to decide by law. The J6 retains the SMEs and subordinate organizations to oversee the DSD's directed guidance.

Who Controls the Resourcing Priorities and Joint Program Office. Few argue for or believe that a Joint Program Office for JADC2 will result in success. However, outside the DoD, this proposed idea emerges from those who perceive interservice rivalry and diverging approaches to JADC2 are resulting in wasted resources and time. The lack of a common lexicon or communication strategy across the Services reinforces this idea. However, most JADC2 developers and industry partners advocate for a bottom-up approach led by Services for JADC2. For the most part, the IS assessed that a Joint Program Office is unnecessary and will likely result in JTRS-like outcomes described in Appendix F of the report. The bottom-up approach requires cross-Service standardization to create integrated processes and necessary programs to enable our national security leaders to act faster than our adversaries. The current JADC2 governance can provide a joint program office's coordination benefit if the CFT takes greater responsibility of synchronizing and standardizing efforts across the Services. The CFT can champion a modified process through the JROC. The team should initiate a series of programs that divides JADC2 phases and LOEs into smaller elements. These smaller programs can then work through the normal JCIDS process, but the goal is to begin work immediately. The division of the process should mitigate the need for capabilities and requirements to be defined from the cradle to the grave before development begins. The smaller programs should work sequentially and simultaneously with later-phase programs starting after their predecessor. The JROC must mandate horizontal integration through the respective programs and link the strategic ends of JADC2 and its development to program initiatives.

Disagreement on Ethics for JADC2 AI and Machine Learning (ML) Interfaces. The JADC2 team encountered internal and external tensions on the role of AI and ML in decision-making for lethal systems. To this end, there is little guidance on the limitations of what AI and ML can or should do to support warfighting. The DoD should inform and educate all stakeholders on the intent and positive impact of JADC2, AI, ML, and Human-Machine Teaming (HMT) to overcome initial apprehension of these technologies. The JADC2 framework will enable information advantages and decision dominance in all domains in the battlespace because it leverages AI and ML. The DoD is already developing and implementing some aspects of AI and HMT to support warfighters while seamlessly integrating the understanding of the technology as a catalyst for data and readiness. The JADC2 CFT and Joint AI Center (JAIC) should establish prescriptive milestones to ensure accountability rules and ethics standards for cutting-edge technology capabilities in AI, ML, and HMT. The DoD should update policies defining the scope and capabilities of JADC2 AI, ML, and HMT to reflect the appropriate level of risk that the DoD is willing to accept. The OSD should publish official policies on AI, ML,

and HMT and better define how capability managers will write AI, ML, and HMT-related requirements. The DoD and the DIB should embed Responsible AI (RAI) ethics data strategy into a larger AI strategy that guides the JADC2 utilization of AI, ML, and HMT.

Push for Common Waveforms as an Area of Misunderstanding. JADC2 evokes an idea that there will be a single standard for C4ISR technology and data or a standard that supersedes other standards. During field studies, the discussion of waveforms came up multiple times as a potential area for JADC2 standardization. Inherent in those advocating for a Joint standard for waveforms is the need to communicate across Services that each uses different waveforms, sometimes on the same equipment and spectrum. Based on issues identified in multiple industry partners attempting to find ways to translate or change waveforms while reducing size, weight, and power, most recommended that the industry coordinate and petition for shared waveforms instead of more proprietary solutions. The IS acknowledges the challenges and requirements for different waveforms for different purposes. However, there are notable cases where waveform standardization across Services on similar or the same types of communications systems could enhance cross-Service communication and data transfer.

The 2020 DoD Communication Waveform Inventory listed 69 waveforms and tactical data links (TDLs) across the DoD. Some waveforms have few use cases but exist because they reside on legacy systems and would cost too much to replace them relative to the benefit of doing so. While each Service has a few waveforms that are specific to them based on unique mission sets, the majority of waveforms are already used across Services (like VHF, VULOS, HF, ANW2, APCO P25, Havequick II/Saturn, Iridium, MUOS, and numerous SATCOM channels). No one-size-fits-all waveform exists because each waveform provides a unique capability. Waveforms and TDLs are transport capabilities. The considerable focus should remain on data standards and increased use of data translation tools already in the field (like TRAX, Rosetta Stone).

Industry partners and Service personnel queried for this report agreed that there is a need to maintain the ability to operate throughout the electromagnetic spectrum to maintain network redundancy and resilience. A better approach for waveforms would be to focus on data standards, data translation tools, and auto PACE (primary, alternate, contingency, emergency) solutions. This debate is a microcosm of the larger nuanced problem of misunderstanding and lack of awareness of JADC2 concept development effort and JADC2 CFT initiatives. Institutionalizing waveform governance and communicating its intent would reinforce the JADC2 CFT's integration role.

Conclusion

In conclusion, the C4ISR IS team evaluated the implementation and understanding of the JADC2 framework by partners in industry, education institutions, and laboratories. Action is abounding in the demonstrated commitment from industry partners and innovation centers. Across the DoD, DIB, innovation hubs, and educational institutions, leaders and innovators seek to advance JADC2's implementation but still do not understand to what end. This report offered insights into how industry will benefit from DoD's institutionalization of JADC2's efforts. It aspired to carry industry's message as assembled from over two dozen engagements. There is a lack of a unifying effort beyond the exploration of new capabilities. Industry and innovation centers fear their supporting efforts may end up wasted and unnecessarily risky. From aggregating findings and inputs from industry partners, implementation efforts so far had hardy innovative approaches. But there is a lack of perceivable follow-through when nothing is codified into a Joint standard. Therefore, industry is left guessing. The Joint Staff leaders guiding the JADC2 efforts can harvest the abundant opportunity provided by innovation centers and industry with more expedient institutionalization of core concepts and synchronizations of DoD-wide JADC2 efforts. In doing so, the pace of industry's response will rival the 1940s industrial mobilization.

It is important to reflect on the challenges facing JADC2 implementation. The IS confirmed that creating this future joint force requires a deliberate and unified process of initialization, implementation, and institutionalization. The Joint Staff's initialization of JADC2 began with the development of the concept and publication of the strategy. JADC2's implementation is making progress, and industry is responding to the demand signals. Nevertheless, JADC2 institutionalization remains absent. Technology and adversaries will not wait for operational concepts and warfighting capabilities to catch up. Now is the time to start creating baselines to build future capabilities. The competitive environment will continue to test the pace of American ingenuity and resolve to defend our core national security objectives. The JADC2 market offers much hope and potential to retain our competitive advantages and deterrence capacity for the foreseeable future. Much progress has been made by the Joint Staff, CCMDs, Services, innovation centers, and industry. Institutionalizing this progress will kindle the fires in the industrial furnaces powering America's defense industrial base to produce unsurpassed capabilities to deter conflict in any environment and, if needed, to win decisively.

Recurring Engagement Themes

Theme 1 (Multiple nuanced interpretations): The understanding of JADC2, its purpose, and its outcomes are not well known or common between agencies, innovation centers, and industry. The JADC2 framework is interpreted differently, and Services have adopted approaches to support it in ways that drive internal efforts. The long-term vision and knowledge of broader JADC2 implementation efforts are only now spreading into the Services after the recent publication of the JADC2 Implementation Plan. Several organizations noted that JADC2 is a complex problem requiring a collective focus on specific elements to enable cross-industry coordination and standardization. These organizations believe that the DoD is trying to solve all the JADC2 issues simultaneously. They observed conflicting and diverging approaches that may create future problems and add time and resources to implement fully. After visiting defense industry partners, academia, innovation hubs, and multiple intelligence agencies, an aligned understanding of JADC2 did not exist. Organizations shared insights on their concerns, ideas, attempted efforts, and ongoing missions and projects based on their unique perceptions of JADC2. However, they did not perceive these efforts as connected to a common set of JADC2 standards or performance mandates. Industry partners requested that the DoD establish an authoritative interface for JADC2 standards and consultation.

Theme 2 (Industry and Innovation Centers are Engaged and Supporting JADC2): Government and non-governmental organizations, industry, and innovators supporting defense modernization are ready and willing to leverage resources and talent to advance JADC2. Most express concerns with the lack of common standards, clear vision, and assured funding commitment to JADC2 as an enduring effort. Regardless, organizations are leveraging opportunities and internal resources to work with the DoD to experiment and develop novel approaches to C4ISR and Mission Command. Companies are leveraging IRAD and innovation centers allocating RDT&E funds to develop JADC2 technologies and upgrade existing systems.

Theme 3 (Policy and Organizational Obstacles Impede Action): Industry and innovation centers identified several roadblocks impacting implementation. The primary obstacles identified during the field studies are policy, bureaucracy, technical limitations, and organizational culture. Policy limitations include security and classification regulations, import-export constraints on sharing and leveraging foreign material and technology, and legal hurdles for acquisition and contract law. Larger organizations have greater capacity to negotiate these hurdles than smaller firms. Technical limitations include platform-specific and network-capacity constraints related to transport, storage, and data processing across multiple networks and classification thresholds. Organizational culture and bureaucracy influence implementation because the size and scope of the JADC2 endeavor crosscuts the entire national security enterprise.

Theme 4 (JADC2's Bottom-Up Approach is Best; Requires Top-Down Coordination): JADC2 is seen as a bottom-up CCMD and Service-led effort. Industry and innovation centers have identified overlapping and repetitive efforts to achieve JADC2. During the field studies, several firms conducted research into similar efforts requested by different agencies or departments, sometimes within the same Service.

Appendix A: 2022 C4ISR Industry Study Individual Research Topics

Although these topic areas guided the group efforts, individual topics overlapped five key focus areas. They provided a multi-dimensional perspective of how the JADC2 CFT's Lines of Efforts matriculated into industry. Specific research topics are below:

Operational and Strategic Environment (see Summarized Findings in Appendix D)

- C4ISR & JADC2 innovation within the Private Sector and adversarial capabilities
- Reviewing Strategic Logic Underpinning JWC and JADC2 and its Potential Flaws
- Ukraine War and Implications for JADC2 and Mission Partners [See Annex A]

JADC2 Implementation and Concept Development (see Summarized Findings in Appendix E)

- Innovation and Experimentation Leveraging the JADC2 DevSecOps Platform Approach
- Use of Low-Code API to integrate disparate systems across Services
- Common Framework Architecture
- Data Analytics & Interoperability
- Navy's Project C4ISR and JADC2 Transformation
- JADC2 and Role of Artificial Intelligence

Concepts and Lessons Learned (see Summarized Findings in Appendix F)

- JADC2 and the Joint Warfighting Concept
- Lessons Learned through JTRS and Recommendations for JADC2
- Comparative Analysis of Amazon and DoD: The Everything Store and The Everything War

Communication and Culture (see Summarized Findings in Appendix G)

- Communicating Change and Managing the Narrative of Innovation in JADC2
- Behavioral Influence to JADC2 Development and Execution
- C4ISR and JADC2 Education and Training Strategy

Organizational Structure and Policy (see Summarized Findings in Appendix H)

- Policy and Authorities for JADC2 Concept Development and Implementation
- JADC2 and the Valley of Death: A Look at Process and Cultural Barriers

Appendix B: Strategic Threat Environment Assessment

After over a decade of fighting a War on Terror, the 2017 National Defense Strategy formally introduced the phrase Great Power Competition (GPC) to describe emerging powers that challenged the world order and presented an uncertain geopolitical future.[44] The military must be prepared to defend against near-peer adversaries on multiple fronts in an increasingly complex environment; in essence, the DoD was charged to fight the "Everything War."[45]

The past year has emphasized the increasingly contentious global security environment in which the U.S. now finds itself, from the withdrawal from Afghanistan, to the Chinese Communist Party (CCP) testing of Taiwan's military responses, to cyber-attacks, and to the ongoing Russo-Ukrainian War, Government leaders have openly acknowledged that the U.S. cannot tackle all global issues by itself, The 2018 National Defense Strategy and 2022 National Defense Strategy Fact Sheet both emphasize alliances and partnerships.[46] The March 2021 Interim National Security Strategic Guidance points out that success will only be "by working in common cause with our closest allies and partners."[47] However, lack of interoperability with mission partners has continued to hamper U.S. efforts to share information and act in concert with allies and partners. One of the five main lines of effort for the JADC2 CFT is the modernization of mission partner information sharing.[48] The continuing Russo-Ukrainian War is a critical example of how information-sharing and coordination can turn the tides of a conflict. The U.S. must figure out how to better share information in a coalition environment across Services and with specific mission partners, not on an emergency or crisis basis, but everyday operations level.

The United States' strategic deterrence is increasingly less effective against adversaries.[49] During recent testimony, defense officials described the need for a new long-term Integrated Strategic Deterrence (ISD) approach to counter the current threats from Chinese and Russian actions and emerging capabilities of all of the U.S. adversaries to decrease the risks of conflict escalation and miscalculation.[50] Senior leaders advocated for modernization and enhancing existing strategic deterrence capabilities that strengthen America's nuclear deterrence, enhance global force projection, and modernize conventional and special forces as the nation aligns all other elements of national power to support these efforts.[51] These efforts call for investments in capabilities that enable that whole-of-government integration. Unfortunately, today's defense enterprise lacks the processes and technological integration that supports optimal decision dominance achievable with these capabilities.[52] The perceived gaps in technology fail to assure national leaders that defense capabilities in the DoD can overcome the increasing capabilities leveraged by adversaries in conflict.[53]

Today, U.S. forces forward deployed against near-peer adversaries must face increasing technological capabilities supporting adversarial systems of systems integration. Over the decades, America's competitors have studied our strengths and weaknesses. They have designed and implemented a system of systems warfare force structure designed to attack the U.S. platform-centric approach. The U.S. previously possessed significant capabilities overmatch over adversaries through overwhelming technologies and capabilities. The DoD understands this dilemma well and has pivoted to transform the employment of forces with the JWC and force structure updates to retain a competitive advantage against great power competitors and regional threats and deter all adversaries from engaging in future conflicts. Over the past several years,

the U.S. military has taken its force structure, primarily organized against large multi-function monolithic platforms, and transitioned to smaller, cheaper, and less multi-functional platforms that can be widely distributed across the globe. This revamped force structure gives commanders more adaptability and scalability while making it more complex for our adversaries to diagnose and understand our approach and disposition. This transition pushes to operationalize data-driven decision-making at echelon by making data available at the point of decision. This method of decision-centric warfighting calls for integrating systems of systems across the Services to access any sensor, delivering that data to any available shooter, and be executed by any commander.[54]

In the current global security environment, adversaries increasingly seek to undermine U.S. strategic and operational strengths by impeding and, where possible, denying C2 capabilities.[55] The ability of the U.S. military to maintain information and decision advantage is inherent in the JADC2 framework. JADC2 provides a coherent approach for shaping future Joint Force C2 capabilities and producing the warfighting capability to sense, make sense, and act at all levels and phases of the war, across all domains, and with partners, to deliver the information advantage at the speed of relevance while acting inside an adversary's decision cycle.[56] The speed of relevance refers to the technological superiority and information dominance on the battlefield.

While the U.S. assesses its approach to the GPC, it should consider the reactionary nature of its adversaries: Russia and China, among others. A helpful framework to use for expanding the U.S. perception of the prey in the great game of GPC is the "Rival as Rationale" model developed by retired Israeli Brigadier General Shimon Naveh.[57] Naveh explains that one must use the known and unknown explicit and implicit variables to define the rival system and how it may employ its forces through various means and ways, such as C2 and battle management, battlespace awareness, and the use of domestic industry.[58]

China's Reactive Approach to the Strategic Environment

China has focused on using every national resource available through centralized control to maximize the benefit to the CCP and the country. Since 2009, China's vital interests have remained the same: "fundamental system and state security; state sovereignty and territorial integrity; and the stable development of the economy and society." [59] In 2011, the CCP expanded these interests to include "peaceful development and national reunification." [60] President Xi has "invoked China's core interests more frequently in dealing with international relations since he was appointed Party and government leader."[61] To secure China's vital interests, China's military strategy "aims to safeguard its sovereignty, security, and development interests" by employing its capabilities in all domains in an integrated "active defense" as it builds a "world-class" military by 2049."[62]

Today, the U.S. cannot use the same deterrence approach as in the Taiwan Straits Crisis of 1996 without facing a more robust Chinese Active Defense capable of anti-access and area denial (A2AD) in all domains. Additionally, China has increased its diplomatic, economic, and legal influence through international bodies and bilateral relations, making it difficult to pressure China. China has adopted a "Three Warfares" approach with industrial policy to gain an information advantage that controls the flow of knowledge, secrets, and beliefs at the highest levels of statecraft to "compete with America's physical network of bases, bombers, and ships."[63]

Mao's central proposition was that "there is … no such thing as a decisive battle; there is nothing comparable to the fixed, passive defense that characterizes orthodox war [where] the transformation of a moving situation into a positional defensive situation never arises."[64] From this fundamental principle, the Chinese concept of Active Defense emerged. Although Active Defense has evolved with the changing character of war, Mao's strategic and operational applications of military power remain at the heart of Chinese warcraft. The U.S. DoD's 2020 China Military Power Report (MPR) describes China's Active Defense as a strategic posture combined with offensive action that is neither a "defensive strategy" nor "limited to territorial defense;" instead, it includes "preemptive aspects" for the People's Republic of China (PRC) to "defend its interests [while] avoiding initiating armed conflict but responding forcefully if challenged."[65] The principle of Active Defense risks a rapid escalation of conflict. Active Defense is more offensive than defensive. As noted in the China MPR, if China determines that "war is unavoidable, [Active Defense] calls for restraining war by taking the opening move and using war to stop war."[66]

Though possessing a larger and more heavily armed military than the Russian Federation, the PRC's People's Liberation Army (PLA) is quite similar in its approach to warfare as Russia. According to the slightly dated book, *Unrestriced Warfare*, the PLA identified the superiority of the U.S. and its allies after the First Gulf War.[67] This assessment encouraged the advancement of PLA doctrine and technological advancement across most warfighting functions. The PLA views enhanced C2 and wider C4ISR as integral to U.S. warfare and future PLA C2 and joint force interoperability and employment.[68] The PLA identifies networked and advanced C4ISR capabilities as essential and critical to its own multi-echelon decision-making; however, it does create similar vulnerabilities in their own system as those they identify in the U.S. Joint Force.[69] If one accepts the veracity of the above assessments, one may further assume that the PRC and PLA decision-makers and commanders view the warfare of the U.S. and its allies remains a superior and pacing threat, thus indicating a reactionary vice proactive PLA that may soon surpass U.S. military capabilities.

Despite this assessment, the concern of a rising, and more capable PLA remains present across most echelons of U.S. decision-making. Nevertheless, there are indicators that despite the technological advancements and modernization of the PLA, advanced and modern A2AD capabilities, and a growing multi-domain force and major C2 reorganizations, serious gaps remain in the PLA defensive wall. There are indicators that the recent command reorganizations from military regional commands to theater commands did not solve the problem of theatre commanders not understanding who has command authority over various units across the PLA.[70] Additionally, many theatre commands do not have the forces to conduct multi-domain operations nor the ability to command and control such formations.[71]

The PLA ability to conduct joint operations also suffers from a lack of joint force mechanisms such as a joint command center and centralized C2 networks to support multi-domain operations across multiple theatres.[72] Additionally, the presence of severe interservice rivalry and command and control competition and sensitivities hamper the ability of the theatre commanders to execute multi-domain and joint C2.[73] These gaps represent a significant vulnerability for the PLA and serve as a possible indicator of the reactive nature of the PLA to U.S. and allied warfighting capabilities and doctrine.

China's National Innovation System. In a meeting with the 19th National Congress of the Communist Party of China in October 2017, Chinese President Xi Jinping laid out an ambitious goal to make China a global leader in innovation.[74] Historically, political instability in China hindered the development of science and technology skills throughout the 20th century. As of the last several decades, in contrast to the U.S., China has established five to ten-year plans noting clear priorities regarding innovation, with policy reforms being the source of significant changes in its NIS. Researchers Aaron Melaas and Fang Zhang found that "in China, the public sector is directly involved in all aspects of innovation, from government agencies that define research objectives to government labs that conduct research and development, and its role in innovation is enhanced by the presence of state-run banks and state-owned enterprises."[75] The Chinese Government has been investing heavily in higher education and conducting research at the Chinese Academy of Science (CAS) and research universities. Like the United States, innovation clusters in Beijing and Shenzhen are stirring innovative growth in China. Research institutes in Beijing led to the explosion of the technology sector, while the Special Economic Zone in Shenzhen was the hub for the technology industry. This investment is paying dividends as Chinese researchers are increasing their share in international scientific publications enabling China to emerge as a significant player in critical areas of research such as artificial intelligence.

The Chinese private sector continues to play an increasingly significant role in the NIS due to a series of political reforms. Over the last decade, the funding structure of China's NIS has changed from one focused on government activity to one that is now focused on the enterprise. Private firms, such as Huawei, Tencent, and Alibaba, have been heavily investing in R&D, with investments totaling $211 billion in 2015.[76] In 2019, amongst China's top 500 firms, 402 companies independently developed key technologies tied to their business, 80.4% of the total. Amongst these same firms, the number of Chinese patents obtained increased by 8.46%, and international patents also significantly increased.[77] Although it appears that China is making great strides in advancing science and technology, most of this activity is concentrated on the imitation or reproduction of foreign innovations. Entrepreneurs in China are often discouraged by educational shortcomings, weak IP rights, and legal restrictions on their activities, and as a result, they remain in short supply or resort to fraudulent activities, such as foreign IP theft which has become common in China. In order to advance Chinese innovation policies, the Chinese Government needs to make it easy to start a new business in China by enforcing transparent laws and regulations, including bankruptcy laws, addressing educational shortcomings that inhibit innovation, and protecting IP rights.

While there are some similarities between the innovation systems of the U.S. and China, one notable difference is that manufacturing is an integral component of the Chinese innovation ecosystem. State investment in production processes has led China to be the world leader in many industries. According to the European Chamber of Commerce, they assessed that "for a generation, China has been the 'factory of the world,' and by 2015, it already produced 24% of the world's power, 28% of the automobiles, 41% of the world's ships, over 50% of the refrigerators, over 60% of the color TV sets, over 80% of the air conditioners and computers, and over 90% of the mobile phones."[78] In comparison, the United States economy has shown very little economic growth, with economists projecting a growth of 3.5% this year.[79] Ahead of the Covid-19 pandemic, Chinese production started moving to Southeast Asian countries, such as Vietnam and Bangladesh, allowing China to reap the benefits of low production costs. Deemed the "world's factory," the Chinese Government, through its "Made in China 2025" initiative, has

plans to reduce Chinese reliance on foreign technology imports by heavily investing in Chinese innovations. Whether this initiative comes to fruition remains to be seen, but it has the U.S. Government considering ways to revive manufacturing in the United States. Fewer goods are produced in the U.S. today, and the U.S. does not have a robust supply chain system to compete with China putting the U.S. at a substantial disadvantage.

Russia Intent and Determination Unknown

One should remain wary of relying upon the recent Russian invasion of Ukraine as an indicator of the success or failures of the modern Russian way of war and its understanding of the U.S. way of war as it relates to the perceived inadequacies of military C2 across all command echelons during the current fight in Ukraine. According to the Center for Naval Analysis (CNA), Russian military doctrine and policy identify C2 as a vital function for its combined arms units and rapid deployment and re-deployment of fires across all echelons as part of a mobile "maneuver defense."[80] This type of warfighting arises from Russian concerns with the outpacing and overwhelming nature of U.S. and allied airpower and existing C2 speed and tempo.[81]

Additionally, the Russian military created a *noncontact* doctrine that resembles U.S. definitions for *deep strike* and *deep area* operations. The Russians developed this doctrine to address what it assesses as the critical importance of information, C2 systems, and precision fires to the U.S. and its allies.[82] *Noncontact* doctrine uses long-range kinetic and non-kinetic fires to disrupt and to degrade adversarial abilities to conduct the initial deployment of the Joint Force and to deploy follow-on forces. Russian military doctrine also states the increasing complexity of their adversaries' C2 capabilities creates multiple points of vulnerability on which to target.[83]

If one accepts the veracity of the above assessments, one may further assume that current Russian military doctrine remains concerned and paces against the Russian perceptions on their own rivals' higher speed, rapid tempo, and technological advancement. The Russian military doctrine related to C2 across all echelons and the employment of fires indicates the Russian military is in a reactionary mode that responds to U.S. and allied doctrine, technological advancements, and practiced employment of forces. This assessment is also indicative in additional doctrine that provides for a "Strategic Defense" as the primary way of war for the Russian military.[84]

Russia's National Innovation System. Like China, the Russian Government has historically played a significant role in the Russian NIS. Today's innovation policies date back to the Soviet Union era when Russia accounted for three-quarters of the R&D expenditure.[85] Since the collapse of the Soviet Union, severe reductions in R&D have impeded innovation. Today, nearly 75% of the R&D is conducted by government agencies.[86] In the last decade, concerns over natural resource dependence led the Russian Government to declare innovation as a priority. As a result, similar to the U.S. and China, the Russian Government launched technology parks such as Skolkovo, partners with academia for R&D, creates academic spin-off firms, and offers venture capital funds to private, small start-up companies. Foreign collaboration is also encouraged, with Skolkovo being a prime example of collaborating with foreign corporations such as Intel and with academic partners such as MIT.

Although the role of private firms is growing slowly, only 20% of these firms conduct R&D as there are very few incentives to do so.[87] Researcher Dina Williams explains that "due to the exceeding scarcity of financial resources for all Russian entrepreneurs, small firms are

heavily dependent on demand for their products. Like many other small businesses, research-based companies start with non-existent or limited assets, and only develop ideas that do not require significant financial resources. In a country with low demand, companies orient their production to cheap products."[88] As a result, very few Russian technology companies can expand to competitive, foreign markets due to low-quality production. Additional factors contribute to low levels of innovation in Russia. Corruption and crime are common in public institutions and agencies. Decreased funding for R&D has led to aging and a decline in research personnel. 87% of research personnel holding a Ph.D. in Science are 50 years of age, and 25% were over the age of 70.[89] The scarcity of funding, income inequality, and lack of IP protection have led many well-educated researchers and scientists to leave the country altogether in hopes of better opportunities overseas. The Russian Government needs to develop a favorable business environment where innovation can flourish.

Recognizing the Continued Threats of More Likely Potential Adversaries

Despite both the strengths and the vulnerabilities of its reactionary near-peer rivals, the U.S. should remain aware that the conflicts in which its forces may conduct JADO in the near-term are not against the Russian and Chinese forces, but rather the more familiar and pernicious threats. These threats include the proxies of the near-peer rivals, the partisans against U.S. partners, and the insurgents that challenge regional and global stability. Low-tech proxy, partisan, or insurgent forces remain an elusive threat to the most advanced JADC2-enabled capabilities of the Joint Force. The use of information warfare, guerilla tactics, and irregular C2 presents the U.S. and its allies with the challenge of balancing its perceptions of the near-peer rivals and the potential threats from North Korea, Iran, and international violent extremist organizations operating in destabilized areas of the world.

The U.S. is in a period where current and future national defense leaders must manage their response to the complexity. In doing so, they must also create conditions or considerations for adversaries' that impede their attempts to do the same. Reducing adversarial certainty about their ability win will reduce their willingness to enter a conflict. This approach is what DARPA termed a new "Mosaic Warfare"[90] in a technical and digitized battlespace.[91] The fundamental concepts of the new JWC explore ways to leverage JADC2 in diverse mission settings. In today's operational environment, there is a struggle for decision dominance. Adversaries employ various forms of warfare across different domains that leverage a technological standoff in the geo-economic and geo-strategic environment ranging from "hybrid activities," military and economic competition in the gray zone, and conflict in a technical and digitized battlespace.[92]

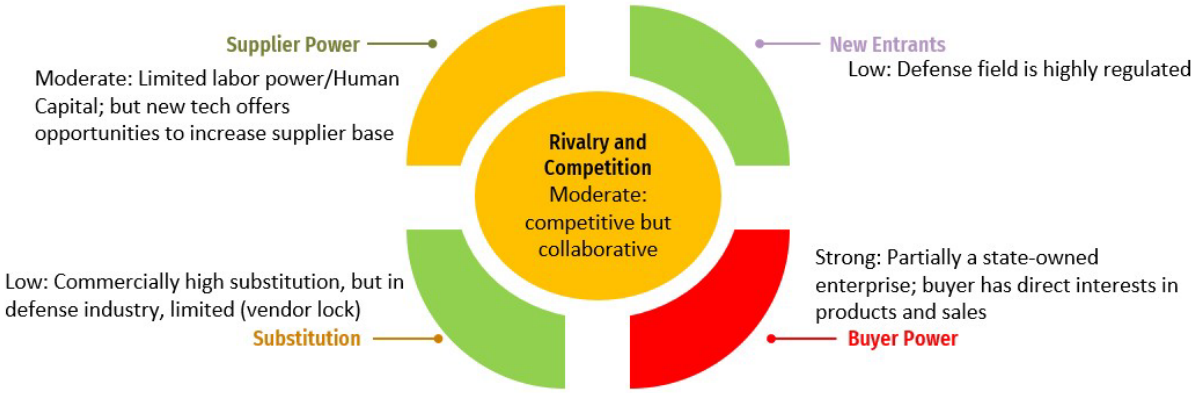
The U.S. must be prepared for a wide array of adversaries that seek to deny, disrupt, and destroy information needed to make decisions to slow us down for relative advantage. Iran continues to threaten U.S. interests in the Middle East while North Korea threatens stability in South East Asia. Both Iran and North Korea continue to develop capabilities similar to China and Russia to counter U.S. conventional and strategic deterrence capabilities. In all cases, information warfare supports adversarial targeting of the U.S. and Allied economic, technical, and military enterprises through other means. All adversaries will leverage hard and soft power activities in the gray zone short of war while employing emerging technological tools, especially those in the cyber domain.[93] Iran and North Korea are observing the advancements with China and Russia to gain understanding of how to advance their own capabilities.

Appendix C: Industry Analysis of Major C4ISR Firms

Defense firms compete based on cost, product quality, and reliability. To survive in the JADC2 market, vendors must produce cost-efficient and high-quality solutions that allow for data access, shared, and used on-demand as the DoD continues to pursue JADC2. Intense competition, frequent changes in policies, and the need for faster, reliable data are critical influences that impact this market. Below are industry analyses of six major defense firms. Of note, three of the six are not creating value for their firms, and only one is a clear creator of value or profitability. While some of this is due to other factors, the lack of profitability should be considered when sending demand signals to industry. If the demand signal is not clear and aligned, companies will be hesitant to invest in an uncertain profit model when they are currently not in an ideal profitability position. JADC2 will likely be software dominant. Not only are traditional defense firms poorly positioned for software development, there is a limited labor pool with the requisite software development skills in the national security field. Finally, software profit margins are smaller compared to hardware profit margins in the defense industry. The commercial software business model does not work in a monopsony situation. A different profit model that works for both the defense industry and individual firms should be considered.

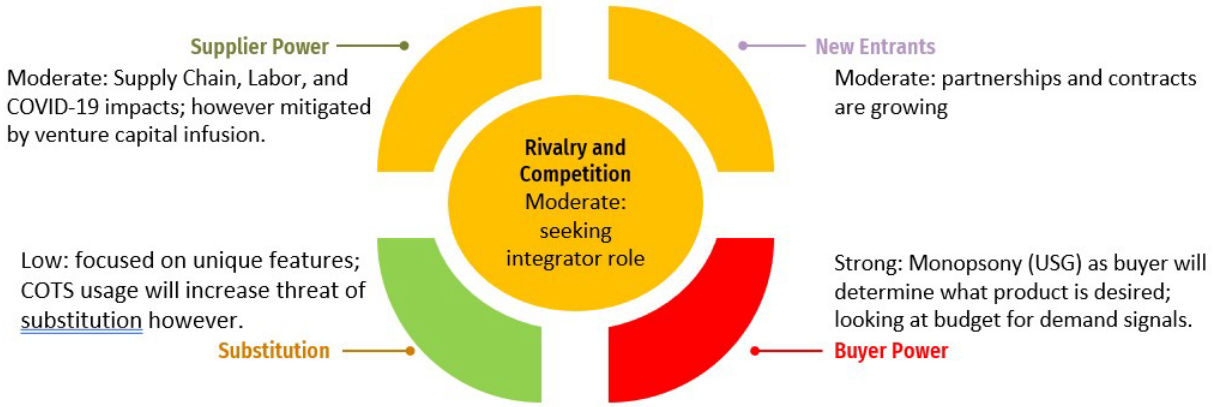
Boeing

The Boeing Company (BA) was founded in 1916 in the Puget Sound region of Washington State, growing to become a leading producer of military and commercial aircraft and eventually a leading global aerospace company. Boeing has years of experience empowering the military with reliable communications and integrating new, cutting-edge capabilities. However, it has been plagued by scandals and mishaps over the past decade, Controversy and corruption surrounding the KC-46 has plagued Boeing for more than two decades.[94] The KC-46 is now part of curriculum on ethics and politics in acquisition.[95] Major blows were dealt to Boeing's commercial business with problems surrounding development and production of its 787 Dreamliner and its 737 Max, which resulted in two deadly and very public crashes in recent years.[96] Finally, the COVID-19 pandemic put pressure on overall travel, both leisure and business, substantially reducing demand for airplanes, Boeing's core business, Currently its return on invested capital (ROIC) (-2.2%) is less than its weighted average cost of capital (WACC) (8.3-10%), and the three credit rating agencies (Moody's, Standard & Poor's, Fitch) have ranked Boeing as moderately risky, increasing its cost of capital, In sum, Boeing has been going through a rough business patch, generating losses, While it is unlikely that Boeing will fail as a company, being too big in its industries to fail, it may require some additional assistance.



L3Harris

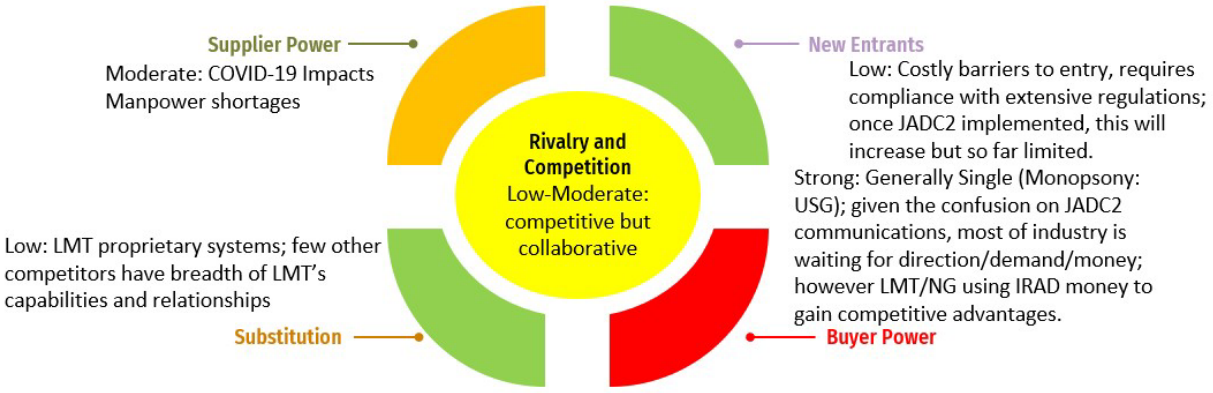
L3Harris Technologies (LHX) is a defense company specializing in communications, surveillance solutions, microwave weaponry, and electronic warfare. It was created by the 2019 merger of L3 Technologies (1997) and Harris Corporation (1895) and is currently listed as the 9th largest defense company for 2021.[97] For 2021, its ROIC was 6.12% which was slightly greater than its WACC of 5.75%, However, its WACC has fluctuated between the 5.75% to as high as 7.5% within the past year, in part due to increased or decreased debt. Thus, though L3Harris is currently creating value, it is borderline and subject to change. Most recently, it has realigned its business segment from four to three, created an innovation unit (Agile Development Group), and partnered with a venture capital firm (Shield Capital), indicating that it is aware of its borderline profitability situation and are aiming to create higher returns by expanding C4ISR efforts. Of note, L3Harris has unique features and expertise not available to many other defense firms. It often partners with other defense firms who utilize L3Harris' expertise.



Lockheed Martin

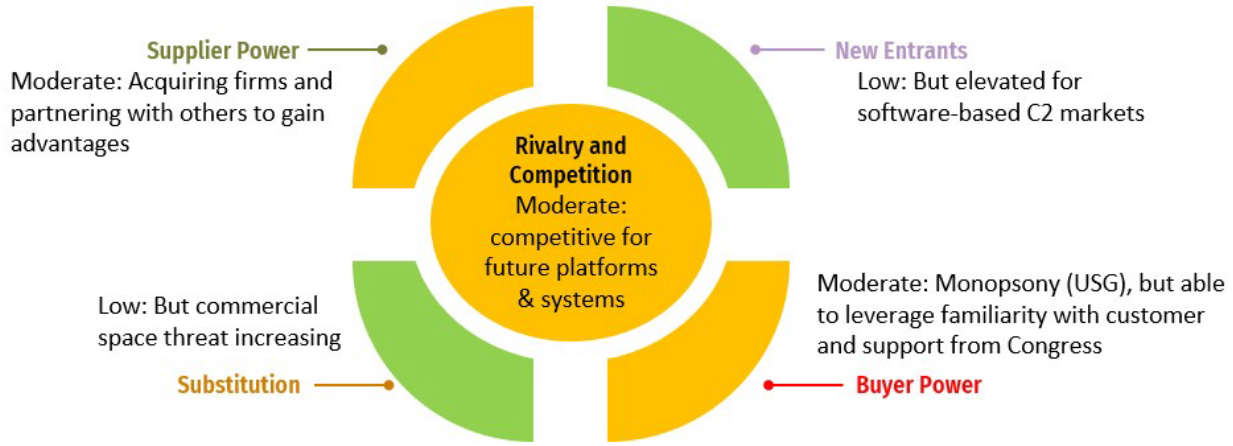
The Lockheed Martin Corporation (LMT) was created in 1995 by the merger of Lockheed Corporation (1926) and Martin Marietta (1961), with residual components spun off into L-3 Communications. Over the years Lockheed Martin has also acquired and sold additional components, most recently abandoning an acquisition attempt for Aerojet Rocketdyne Holdings

in 2022 following regulatory disapproval. Its sales are primarily to the U.S. government, 71% or $48.2 billion.[98] Lockheed Martin has consistently been ranked the number one defense company for the past 21 years, with an estimated 96% of revenue coming from defense.[99] It has been doing very well with ROIC (17%) greater than WACC (5.5-6.5%), and particularly in the C4ISR industry. It has significant advantages in profit, capturing the largest share of DoD spending amongst defense firms, with enough cash on hand to simultaneously seek acquisitions, pay dividends, and repurchase outstanding shares. It also is well-positioned for the JADC2 market because of existing Lockheed Martin systems in use currently by DoD.



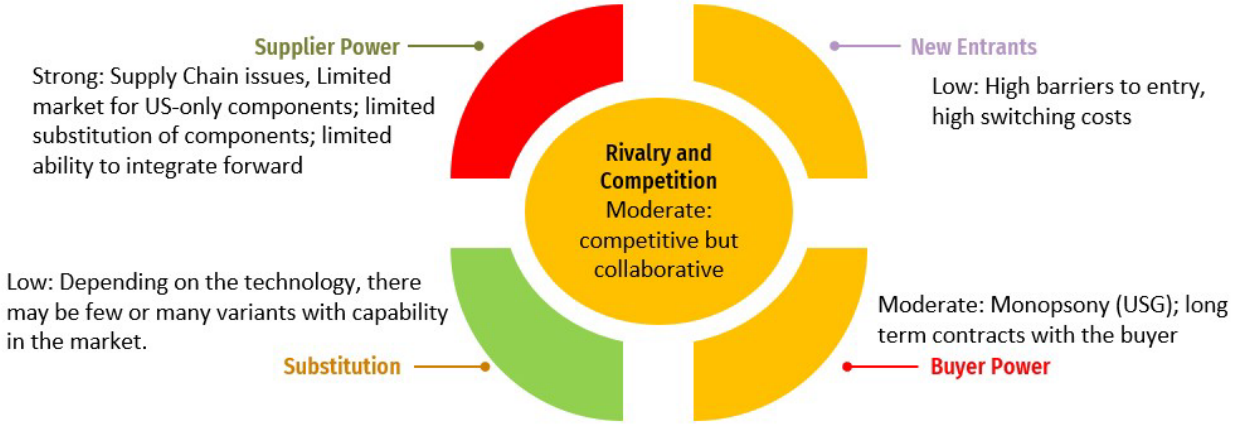
Northrop Grumman

Northrop Grumman was created in 1994 by the merger of Northrop Corporation (1939) and Grumman Corporation (1930). It is an aerospace and defense technology company, considered one of the top defense companies, currently ranked fourth for 2021.[100] Each of its four business segments have ROICs (9%-15%) greater than its WACC (7.2-8.5%). It is currently creating value. It is currently looking to expand its Space Systems business segment, which has a business segment ROIC of 10%, hoping to increase sales by 50%. It has also taken steps to position itself for future innovation, partnering Antelope Valley Community College to groom STEM and fabrication and repair talent. Though it does not win all programs on which it bids, Northrop Grumman partners with the winning prime, often securing a subprime position as a key supplier, It currently provides critical defense systems to DoD and is expending IRAD funds to align its own products in anticipation of JADC2 efforts and future sales.



Raytheon

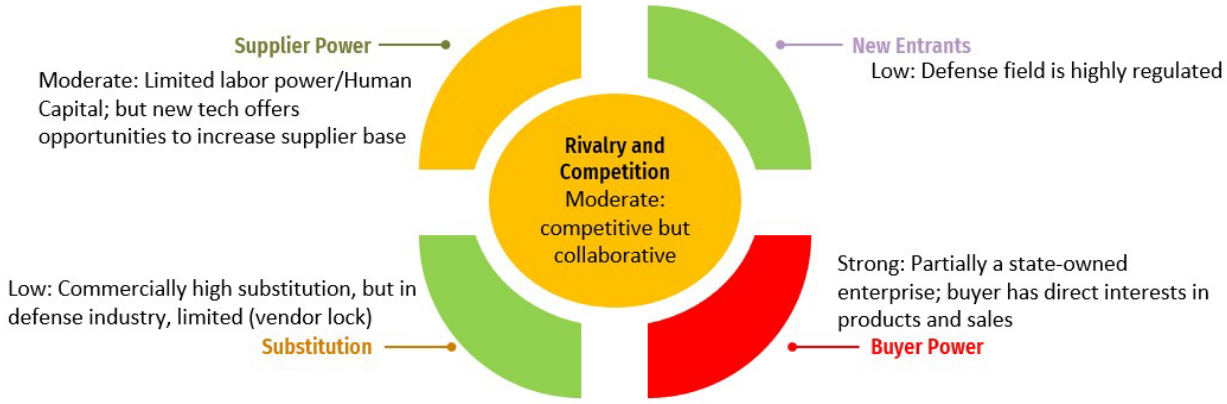
Raytheon Technologies Corporation (RTX) was created in 2020 by the merger of United Technologies Corporation (1934) and the Raytheon Company (1922), It is an aerospace and defense conglomerate, providing aerospace, intelligence services, and defense manufacturing. It is considered the second largest defense company in the world for 2021, following its 2020 merger from 2020 5th-ranked Raytheon Company and 10th-ranked United Technologies Corporation.[101] However, despite its ranking, it has not be performing as well, For 2021, its ROIC was only approximately 3.1% compared to its WACC (7.5-8.5%).[102] Thus it is not currently creating value. This may be a result of adjustments to its recent major merger. They are continuing plans to expand their global customer base and partnerships to strengthen relationships with local customers. However, a review of their recent products well-positions them for the C4ISR industry, and specifically the JADC2 market. For example, they are developing a modeling and simulation environment to help drive down costs of development and prototyping. They are also pursuing vertical integration of RTX products, which is in line with JADC2 efforts. Overall, Raytheon Technologies has strengthened its core business through its R&D activities, which are focusing on product development for the U.S. government.



Thales

Thales Group is a French company specializing in electrical systems, providing services for aerospace, defense, transportation, and security. It was renamed to Thales after a 2000 acquisition of Racal Electronics. It had been previously known as Thomson-CSF (1968) and Compagnie Française Thomson-Houston (1893) before that. It is partially owned by the French government. It has a 50:50 joint venture with Raytheon for ThalesRaytheonSystems (2001), focusing on radio and communications, which in 2016 focused on NATO agencies and member states. Its 2020 ROIC (-2.5%) was less than its WACC (4.72%), indicating that it is losing value. Its 2021 numbers improved (estimated ROIC 4.16%), but its WACC is greater than its ROIC.[103]

Thales is listed as the top 16th defense firm for 2021.[104] However, it is considered number one globally for digital identity and security, which operating sector contributes to 18% of Thales' profitability. Thales itself emphasizes data and trust as its focus. It is also considered number one in Europe for defense and security, which operating sector contributes to 48% of Thales' profitability. It is considered to have exceptional research and development, with over $1.1 billion IRAD spent in 2020. Eleven European NATO allies utilize Thales technology as the primary architecture of their C4ISR systems, Considering that JADC2 focuses on digital identity and security and seeks to incorporate mission partner intelligence sharing and interoperability, Thales will definitely be included in JADC2 implementation efforts.



Global C4ISR Industry Analysis and Global JADC2-like Efforts

Although Russia remains a greater immediate threat to the U.S., SecDef Lloyd Austin and GEN Mark Milley testified to Congress that the enduring challenge for the U.S. is China's military advancements. China and Russia increased investment and revamped their military capabilities over the last two decades. Per the Interagency Task Force in Fulfillment of Executive Order 13806, "In 2001, China's annual military budget was less than $20 billion. By 2017, it exceeded $150 billion, second only to the U.S."[105] Among all adversaries, China leads with significant financial investments in technology to surpass the United States in a technological war. China's economy is expected to grow 5.1% in 2022 due to the number of goods China manufactures and investments in initiatives such as Made in China 2025 and the Belt and Road Initiative.[106] China has also adopted a "Three Warfares" approach with industrial policy to gain an information advantage in the flow of knowledge, secrets, and beliefs at the highest levels of statecraft to "compete with America's physical network of bases, bombers, and ships."[107]

In the last two decades, China built massive whole-of-government and whole-of-society mobilization networks to align state and private resources to national security objectives. The result is a growing gap between the mobilization capacity of the United States' two greatest adversaries and its own. In 2014, the United States began a technological standoff manifesting in the geo-economic and geo-strategic environment. It started when Secretary Robert Work announced the Defense Innovation Initiative and its Third Offset Strategy in a speech at the National Defense University.[108] In its wake, China and Russia redoubled their whole-of-society modernization through technological and security investments. China's more extensive industrial and economic base makes it the enduring pacing threat outlined in the 2021 Interim National Security Guidance. China's investments attempt to deny the U.S. access, space, and time to dictate their future freedom of action. [109] A primary target of these efforts is to out-develop and out-produce the U.S. in critical emerging technological areas that enable China to gain dominance in the information domain by controlling knowledge, secrets, and beliefs. In this arena, China sought to gain intelligence and intellectual property to counter U.S. technological advantages in future conflicts and increase their "hybrid activities" and economic competition in the gray zone.[110] While Russia takes an *offensive approach* near-abroad, China takes an *active defense* approach in the South China Seas and invests in global access through the Belt and Road Initiative.[111]

Appendix D: JADC2 Industry Operating Environment Assessment

Current Assessment of C4ISR and JADC2 Research and Development Innovation Centers

Innovation is defined as the implementation of ideas resulting in new and improved products and services that provide value. The United States NIS can be described as a "triple helix" – a collaboration between the government, academia, and the private sector. Historically, the United States has had a deep-rooted culture of risk-taking and entrepreneurship due to American consumerism putting pressure on firms to innovate. Per Researcher Robert Atkinson, "the 'venturesome consumption' nature of American consumers—that is, their eagerness to be early adopters of and experiment with new products and technologies—has played a role in supporting U.S. innovation success."[112]

After WWII, the federal government played a significant role in funding R&D laboratories and research universities driving innovation in industries such as aviation, energy, defense, and pharmaceuticals. By the 1960s, the federal government invested more in R&D than any foreign government or business.[113] To secure the United States' position as a global leader in a host of advanced industries, the federal government established organizations such as the Atomic Energy Commission in 1946, the first Federally Funded Research Development Center (FFRDC)—RAND—in 1947, the National Science Foundation (NSF) in 1950, and the Defense Advanced Research Projects Agency (DARPA) and NASA in 1958. Present-day, the federal government funds between 80 and 100 government research laboratories to help government agencies achieve mission goals. DARPA, for example, has played a significant role in the development of cutting-edge technology that was initially designed for the military, but has since spun off to the domestic and international economy,

In addition to funding government research laboratories, the federal government collaborates with academic research institutions such as the University of Texas at Austin, the University of Virginia (UVA), and the Massachusetts Institute of Technology (MIT) to explore academic solutions to existing problems or to think of and design technology for future needs that may arise. One university might partner with other universities to support a government contract, allowing those with different skillsets to tackle a widespread problem. The private sector also funds and collaborates with academic research institutions. Per Researcher Robert Atkinson, "the ability of some leading U.S. universities to work cooperatively with industry has been key to driving regional innovation hubs and clusters. These collaborative learning systems, especially in clusters, are supported in part by strong IP protections—people aren't afraid that if they talk and share they will lose proprietary IP."[114] Public-Private partnerships are essential for encouraging and fostering innovation in the United States. The Boeing Company, for example, funds MIT projects, such as the Wright Brothers Wind Tunnel, and partners with the academic institution to explore and advance aerospace innovation, supporting the C4ISR needs of the U.S. military.

When it comes to innovation in the private sector, the United States NIS places few barriers to entry for new firms breaking into existing markets, thus increasing competition. In 2020, the United States ranked sixth on the World Bank Index for ease of starting a business, behind nations including New Zealand, Singapore, Denmark, and South Korea.[115] As a result, most commercial activities today are conducted by the private sector. The federal government

does not directly support R&D in private firms unless it is tied to achieving a core mission, especially in defense. This decision is in part due to the belief that private firms are better positioned to identify the areas of most commercial promise.

Some state governments have established venture funding programs to help small, early-stage start-up companies. These programs allow start-up companies to connect with the venture capital industry, which has been funding many high-growth investment opportunities. In addition to providing funding, many wealthy venture capitalists serve on company boards managing critical business functions and advising on business strategy. The amount of venture investing has grown significantly in the last decade, with the value of deal investment growing 4.6 times from 2006 to 2019.[116] A majority of this investment has been concentrated in areas like Silicon Valley, Research Triangle Park in North Carolina, and Massachusetts.

In 2018, the DoD established the Defense Innovation Unit (DIU) to better connect with the private sector. The DIU "strengthens [U.S.] national security by accelerating the adoption of commercial technology throughout the military and growing the national security innovation base."[117] The DIU engages with the private sector, from venture-backed small start-ups to top defense firms, to find commercial solutions to military Service problems. Often, the DIU connects with the top four private firms that dominate the United States defense industry: The Boeing Company, Lockheed Martin, Northrup Grumman, and Raytheon. In order to support the growing needs of the United States and foreign governments and commercial customers, efforts to support innovation within these firms include internal R&D, collaborative partnerships with the United States and foreign firms, acquiring smaller firms, and competing for national awards like the Collier Trophy. The Boeing Company, for example, invests more than $3 billion annually in R&D, more than any other United States defense company.[118] Collaborative partnerships, in and outside the United States, are also vital to supporting the growth of the United States NIS. In 2019, for example, the Israeli company Elbit Systems also partnered with The Boeing Company to supply structural components for the F-15 aircraft.

Challenges with the United States' National Innovation System

With the reemergence of the Great Power Competition, innovating in the 21st century will present several notable challenges to the United States. The first challenge is the erosion of the United States' economic and technology dominance. Political dysfunction and the Budget Control Act of 2011 have led to a substantial cut in defense spending in the past decade. A decrease in defense spending impacts investment in new military equipment and technology and hampers the ability to fully plan for future conflicts.

The second challenge that the United States faces is inefficient government business and procurement practices. Since the 1980s, the average time required to develop a major defense acquisition program has been approximately eight years. This slow cycle time is leading to increased production in outdated technology. Given the average eight-year cycle time for a major defense acquisition program, the United States Army Aviation and Missile Research, Development, and Engineering Center estimate that "70% of electronics procured by DoD are obsolete prior to system fielding."[119]

Many of the current government policies strain the industrial base while shrinking incentives to do business with the United States Government, resulting in a failure to meet national security demands. One such example is the Federal Acquisition Regulation Part 15,

which requires private sector companies to either replace existing accounting systems or develop a new accounting system equivalent to the DoD's Cost Accounting System. In addition, the excessive time and cost associated with obtaining key certifications, security clearances, and meeting IT and software requirements necessary inhibit private sector companies from doing business with the DoD. The United States Government needs to re-assess existing business and procurement policies quarterly to minimize inefficiencies within the system. Acquisition lifecycles need to be trimmed to two to five years to limit the production and procurement of outdated technology.

The third challenge is the shortage of skilled labor, especially in STEM fields. For many years, the United States was the world's innovation hub, with Silicon Valley leading advancements in technology. Today, adversaries like China and Russia have invested heavily in STEM talent and are exploiting this American vulnerability. Per the Interagency Task Force in Fulfillment of Executive Order 13806, "Growth in advanced science and engineering degrees shows the U.S. graduating the largest number of doctorate recipients of any individual country, but 37% were earned by temporary visa holders with as many 25% of STEM graduates in the U.S. being Chinese nationals."[120] The United States public and private sectors compete for the same STEM talent, and the education system is not providing the resources to meet current and future demands. The United States relies on its immigration policies to recruit and hire top technical talent from overseas. The immigration cap changes over time, and the length of stay for these applicants also varies. Today, this measure alone is not sufficient to compete with adversaries. The immigration system requires reforms to allow additional talent to enter the United States. In addition, the United States education system requires reforms to introduce STEM subjects to children in grade levels as young as first grade. Future conflicts will be more technical in nature than physical, and the United States is at a significant disadvantage due to a diminishing talent pool of STEM graduates.

Appendix E: JADC2 Capabilities Development Assessment

Current Assessment of JADC2 Applications Emerging from Industry

Industry is making significant progress in the development of JADC2 supporting capabilities. The following assessment describes these efforts and related challenges. The JADC2 framework pursues the development of emerging technology and innovative solutions in predictive analytics, artificial intelligence, and machine learning to speed up our ability to employ our warfighting platforms and capabilities at every echelon at any phase of the conflict continuum and in Denied, Degraded, Intermittent and Limited (DDIL) bandwidth environment.[121] Integrating data through hybrid-cloud and fog computing to joint mission systems at the tactical edge will be critical to successfully implementing the JADC2 framework.[122]

Achieving JADC2 Objectives Using Application Programming Interfaces

Developing resource definition format-agnostic Application Programming Interfaces (API) that can manage different data streams and formats will be a significant milestone driving data integration will be an essential link to support this new warfighting concept.

Integration through Resource Definition Format-Agnostic APIs. API is a software intermediary that allows two or more applications to pass data traffic to each other. Many of our warfighting functions use management systems that deliver a specific application and process that either supports other warfighting systems or is consolidated in a Common Operating Picture (COP). APIs use streams of data that represent various formats, such as JavaScript Object Notation (JSON), eXtensible Markup Language (XML), and HyperText Markup Language (HTML), to name a few of the more popular open resource representation formats.[123] Accounting for the proprietary resource representation formats from commercial vendors and those supporting the systems of warfighting platforms across the Joint Force, the amount of resource representation formats available presents an enormous challenge to data integrators supporting the JADC2 framework. One approach to address this issue is developing resource representation format-agnostic APIs. An opportunity to aid in developing a resource definition format-agnostic API to support our warfighting mission systems is using commercial low-code API platforms managed by warfighters at the tactical edge across the joint force. Low-code platforms like these have demonstrated their capability to support the integration of data from old legacy platforms to newer and modernized systems that deliver tailorable and relevant data to the warfighters at the tactical edge. These low-code platforms can generate source code for APIs and store in aggregate warfighting functions and capabilities that can help prescribe standard resourcing formats across each Service and the joint force. Interfaces related to code are like a contract that defines a specified type of action. Any changes to what have been previously agreed upon within that contract will often require a new contract, and as it applies to APIs, the code will certainly need to be rewritten. Low-code platforms allow the warfighters at the edge of tactical operations to negotiate contracts on their terms and integrate systems by adjusting code in APIs to support the distributed decision-support capability requirements unique within their organizations. Many Services already leverage low-code platforms to develop APIs to support the requirements unique to their operational needs. Organizations such as the Army Future Command's Software Factory[124] and the USAF AFWERX[125] have developed software to

integrate warfighting systems supporting their Service-centric warfighting platforms and were adapted across their enterprise network. Lower echelon organizations such as the 480th/363rd ISR Wing, USAF, and 18th/1st Corps, USA have also leveraged the integration capabilities of low-code platforms to support the integration of C4ISR systems at the tactical edge of operations. There are instances where these low-code platforms have helped organizations at the lowest echelon improve routine administrative and sustainment tasks in garrison through the integration of functions presented in mobile applications, some being adopted and implemented as common tools to aid in these functions across their Service.

Adding Resource Definition Format-Agnostic APIs as a requirement to the Modular Open Systems Approach (MOSA). The DoD's preferred method is a Modular Open Systems Approach (MOSA)[126] and is prescribed as U.S. law Title 10 U.S.C. 2446a(b), Sec 805 stating that all Major Defense Acquisition Programs (MDAP) must meet the requirements "that employs a modular design that uses major system interfaces between a major system platform and a major system component, between major system components, or between major system platforms; is subjected to verification to ensure major system interfaces comply with, if available and suitable, widely supported and consensus-based standards; and uses a system architecture that allows severable major system components at the appropriate level to be incrementally added, removed, or replaced throughout the life cycle of a major system platform to afford opportunities for enhanced competition and innovation." The integration of older systems supporting our warfighting platforms into newer modernized systems and those operated by our international mission partners will require standards prescribing a resource definition format-agnostic API as part of technical and business strategy for designing affordable and adaptable systems.

Low-code API platforms integrate programs and systems at the tactical edge. Coding software in the military should be done at tiered levels of hierarchy and control. Commanders at the tactical edge such as ISR Wings and Brigade Combat Teams (BCT) up to operational commands have talented Servicemembers that can execute basic level (Tier 0) coding through low-code API platforms to support the tactical and operational integration requirements to speed up decision making, improve processes, and increase efficiency in supporting its operational and tactical needs. Commanders across operational and support organizations at these echelons executing Tier 0 coding can forego traditional contractual procedures in procuring software by using low-code platforms to model, simulate, and test code to integrate internal and external systems into their organization and Service. Low-code API platforms will not replace traditional software developers. There will continue to be a requirement for higher-tiered coders across each Service to develop software supporting emerging technologies in artificial intelligence, machine learning, robotics, and other groundbreaking technologies. Basic level (Tier 0) coding through low-code platforms provides an option for lower-tiered echelons across the force to resolve their software-related integration issues at their timeline and operational need. They are simply an option to free up time and resources for higher-tiered junior to senior level (Tier 1-3) software developers to focus on more complicated and prioritized tasks.[127]

Low-code platforms help support the development of resource definition format-agnostic APIs. An enormous challenge in using meta-data to meet our tactical and operational requirements is managing the *volume (amount of data), velocity (how fast data changes and is received), and variety (different format types)*[128] of data that must be processed and analyzed. On average, the public and private sectors currently spend 80% of their time preparing the data and 20% analyzing it before it can become useable[129]. That useable data is then categorized or

curated for use to support requirements in sensor to shooter mission systems, integration of various warfighting systems consolidated in a common operating picture, or as algorithms for AI, predictive analytics, and ML to support the speed of decision making. As we approach an era where multi-cloud solutions become agnostic to the warfighter, we must define how we deal with meta-data management to deliver data at the point of decision making. Low-code API platforms can support the development of aggregated APIs by warfighting functions across each Service and Joint Force. This aggregated API can serve as the foundation for determining various resource formats that can map out the development of resource definition format-agnostic API software.

Tendency to over-rely on the industry to develop software for systems integrations. Over the past decades, the DoD has relied on industry to develop most of the software used by our warfighting systems and platforms. The tendency to rely on industry to build code has only increased with the emergence of AI and ML, algorithms supporting our autonomous and robotics, and predictive analysis to support our decision-making. Not all code is this complicated, and coordination from Service-specific DevSecOps organizations can help model, experiment, and simulate new code development. Lower echelon organizations at the tactical and operational commands can expand on source code developed from low-code platforms to integrate more complex functions and applications as plug-ins to existing warfighting systems. In addition, source code from low-code API platforms serves as the base for integrating legacy and international partner systems where proprietary interfaces or none previously existed to support lateral and vertical systems integration.

Challenges with systems integration supporting JADC2 framework. There are inherent challenges to implementing a resource definition format-agnostic API to support the integration of warfighting systems that were not designed to be interconnected.

Stove-piped Programs of Record. There are inherent challenges to implementing a resource definition format-agnostic API to support the integration of warfighting systems that were not designed to be interconnected. Warfighting platforms and associated systems to manage it are consolidated into Programs of Record (PoR). Many do not allow for an open interface architecture, and an interface to add applications and functions often does not exist. In addition, Program Managers (PM) are often reluctant to let anyone outside the program apply external software or code supporting resource agnostic APIs within their systems. Adopting resource agnostic APIs into MOSA can fix this issue by forcing PMs to include these types of software interfaces to be applied or have them delivered as a requirement in the contract.

Platform centric budgeting process. Platform-centric budgeting as an acquisition strategy and the Planning, Programming, Budgeting, and Execution (PPBE) process encourages PMs to manage PoRs to the specification in which it was acquired. The new system of systems concept of warfighting will require rapid changes in how we process, route, and receive data from various platforms managed under different programs and commercial systems not currently in the DoD inventory. A rigid PoR focused acquisition strategy will only hinder how we integrate other systems in the future. As an alternative, adapting a mission-focused budgeting approach where funding is set aside for the systems supporting specified missions, i.e., the defense of a sovereign state, leaves room for resource managers to integrate new and old systems that fit the requirements that support that budgeted mission.

Standards in software development can be too descriptive if not properly managed. Military standardization can be perceived as rigid and strictly structured. The emphasis on standards has been the focal point for success in the military, enforcing discipline, and a unified effort to accomplish a common objective. While critically important in the military, software development standardization that's spurred the applications development widely used in our personal lives has a more natural approach for accepting the best program or code to achieve the specified function for the most users. Developing an overly specified and descriptive standard in software development can pose a risk to the integration of future and legacy systems supporting warfighting platforms. DoD must establish software development standards that nudge the industry, research labs, and "in-house" tier 0 coders to move in the spirit of guidance towards integrating systems supporting JADC2 framework without being too descriptive and stifling innovation and creativity. Standards towards integration should be *descriptive without being too prescriptive* if we want to achieve deliverables in the JADC2 framework.

Focus on Ad-hoc vs. persistent interoperability. The cultural difference across our Services is a competitive advantage. The diversity stemming from how each Service approaches the implementation of JADC2 framework to support future conflicts gives us resiliency and flexibility to rapidly adapt and overcome our adversary's best effort. Our international allies and partners will continue to invest in systems and platforms that will continue to challenge interoperability today and in the future. Integrating systems across the joint force will be a persistent requirement to support data-driven decision-making at echelon. We need to consider other alternatives such as a continuous interoperability approach as it applies to the system of systems warfighting architecture. A persistent data connection to a smaller and much wider dispersed combat platform at the tactical edge across Services can be costly, unsustainable, and challenging to execute. As an alternative, on-demand or ad hoc interoperability of systems through resource representation format-agnostic APIs through automation has the potential to achieve similar end states as the current approach for persistent interoperability. Through an ad hoc interoperability approach, warfighters at the tactical edge can push and pull specifically targeted data supporting data-driven decision-making by making relevant data available to the specified warfighting platforms only when needed. Today we can implement ad hoc interoperability of our systems through sets of rules that can automate how we manage data for our warfighters. As algorithms mature, more efficient methods using artificial intelligence and machine learning can be applied to support this interface resource representation format-agnostic API approach to data management and increase the speed of delivery for relevant data.

Artificial Intelligence and Machine Learning to Power JADC2

AI is the science and engineering of making intelligent software and machines.[130] AI and ML are critical enablers for JADC2. AI, ML, and HMT enable Warfighters to make informed decisions at the speed of relevance. Defense AI focuses on speed and scale. In other words, the speed of information delivery can have significant strategic and tactical impacts on Warfighters, so they can make data-informed decisions before adversaries have time to act.[131] The spectrum dominance of the tactical implications allows the Warfighter to communicate, sense, and defeat on the battlefield.

Current State of AI Development for JADC2. The DoD does not have a common understanding of terms and concepts within the AI portfolio. This lack of common knowledge has led to conflicting guidance and a blurred narrative of the end state for AI or its application to

JADC2. In the first decades of the 21st century, highly mathematical-statistical machine learning dominated the AI/ML field. This technique has proved highly successful, helping to solve many challenging problems throughout industry and academia.[132] AI and ML shortens the sensor to shooter kill-chain where the sensor to shooter network design provides optimal data. AI and ML are encouraging in the field of gaming. Employing similar techniques for some C2 functions will remain challenging given the real-world barriers of incomplete information, poor data quality, and adversary behaviors and actions. Yet, warfare gaming will be more readily applicable for the operational environment, such as predicting aircraft status in theater, because it is easier for AI and ML techniques. However, AI and ML continue to be a challenge despite recent successes in Human-Machine Teaming (HMT). AI JADC2 goals depend on identifying the C2 needs of core military mission sets and establishing achievable software development plans in the near and far terms. Soon, many artificially intelligent, networked things will populate the future battlefield, operating in close collaboration with human warfighters and fighting as teams in highly adversarial environments.

The ADEPT Framework. The AI Design Engineering for People and Technology (ADEPT) framework standardizes the AI lexicon of key terms and concepts across multiple disciplines and share AI implementation lessons learned between implementing organizations and disciplines. It provides fidelity in developing AI top/high-level requirements using a system engineering approach.[133] The significance of ADEPT is that it enables Warfighters to achieve decision advantages through AI-enabled mission threads. The ADEPT framework articulates a common understanding of key terms value-added to JADC2:

> Narrow AI develops AI task-by-task in a mission thread; operational AI focuses on decision-making and actions. ML is composed of technical approaches to AI development. Type II AI predetermines models trained on available data using machine learning, and Type III AI concludes directly from analyzed operational data. Automation is a method to achieve autonomy, equating to the machine's independence. HMT reinforces the importance of human and machine interactions to further the speed of data for the warfighter to make informed decisions. C2 guiding functions improve warfighting capabilities to sense, make sense, and act.[134]

Sense is the ability to discover, collect, correlate, aggregate, process, and exploit data from all domains and sources, such as friendly, adversary, and neutral, then share the information as the basis for understanding and decision-making. Make sense refers to analyzing data to understand better and predict the operational environment, the actions and intentions of an adversary, and the actions of our friendly forces; sense-making, data transforms into information, and information transforms into knowledge. To act is to make and disseminate decisions to the Joint Force and its mission partners.[135] The human elements of decision-making combined with the technical means to perceive, understand, and predict the actions and intentions of adversaries. The quickest way to get data to the warfighter is via AI rendering faster computers, algorithmic improvements, and access to large amounts of data-enabled advances in ML and perception; data-hungry deep learning methods dominated accuracy benchmarks around 2012.[136] Northrop Grumman has a contract to apply AI models in "Gamebreaker," a United States Defense Advanced Research Projects Agency (DARPA) program.[137] The AI models appear to be cutting-edge on warfare readiness, and the model will allow deployment of Command, AI in real-time wargaming. The current state-of-the-field of warfighting utilizes AI/ML and HMT. AI and robotics enhance human performance and readiness. HMT increases lethality through the range,

endurance, payload, survivability, and adaptability, significantly changing carrier employment strategies. Quantitative studies and applied research have been proven to support AI/ML and HMT.

SDN2 Manifesting into JADC2 Progress

Software-defined networking (SDN) is a cloud-based network architecture that provides an alternative for hosting networks on stationary servers. The market has two segments; firms are either infrastructure designers or service providers. This analysis looks at the infrastructure design market. In 2020, the COVID-19 pandemic accelerated the growth of the SDN market. Two factors have contributed to this boom. First, COVID mitigations increased usage of virtual platforms placing strains on traditional network architecture.[138] Second, supply chain challenges exposed the inability of traditional networks to support the increased data transfer needed to redirect operations. As a result, commercial and public sector organizations sought SDN solutions to build flexible networks that could grow with demand.[139] The current buyers in the SDN market are telecommunications firms, academic institutions, healthcare facilities, logistics hubs, and transportation companies.

This market will continue growing over the next five years as organizations pivot business practices to meet newly exposed data and information network needs. We can also expect the digital transformation of Chinese and Indian industries to push demand for several years. SDN has also gained growing interest in the defense and security industries. The architecture provides a centralized platform for various communication and data nodes to talk more seamlessly. Additionally, designers can build redundancies into the network to ensure continuity of communication in degraded environments. As firms in the market develop SDN controller security and encryption capabilities, there is increased potential for using the architecture as the backbone for multi-nodal cross-domain networks.[140]

Governments across the globe are transitioning critical information systems to SDN. For example, Middle Eastern aviation authorities purchased SDN architecture for airport security and air traffic control systems. European militaries and government ministries are experimenting with SDN architecture as the backbone for their radio and command network communication systems.[141] U.S. agencies are migrating some unclassified networks to SDN architecture. However, they have not integrated them into C2 systems.[142] Though the technology is not new, the SDN market is relatively immature, with small to medium start-ups dominating the field.[143] Large network design firms like Cisco and VMWare, Inc. have acquired start-ups to hedge their position in the field.[144] Telecommunications firms are also acquiring start-ups, which appears to be an attempt to protect their position in the wireless network provider markets.[145] Defense firms, such as Thales and L3 Harris, are currently using in-house capabilities to build their defense and security-related SDN offerings. However, they are likely to acquire smaller firms as they build new network security technologies.

The SDN market is highly competitive. Though multiple firms are providing similar offerings, demand currently exceeds production capacity. Several conditions make the environment beneficial to firms competing in this market. First, SDN architecture is the current market substitute; it is the alternative to server-based information systems and router-based wireless networks. For this reason, there are few, if any, alternatives for consumers who are

interested in improving the flexibility of their current information systems. Next, digitization creates advantages for firms entering the market. It speeds up their ability to adapt technology offerings and maintain a competitive advantage in the market. It also decreases the cost for new firms to enter and operate. Last, the market's immaturity provides advantages to new entrants in that most firms are still fighting for brand recognition.[146] New firms can still benefit from the first-mover advantage. Large firms see value in the market but have been slow to enter. As we continue to see the market grow, we can expect to see established firms increasingly acquiring smaller firms to protect their market share.

While the market outlook is favorable for firms operating in the SDN market, two factors can negatively impact competitiveness. Like other emerging technologies, building SDN architecture requires a highly skilled labor force. Meeting labor market needs requires significant investments in human capital.[147] While the long-term savings of SDN networks are attractive, the upfront costs of network migration are relatively high and potentially prohibitive for small to medium-sized buyers.[148] The SDN market environment is one of perfect competition. Demand drives growth opportunities for firms—ingenuity powers firms' ability to improve business practices and products to meet consumer needs. These forces work in concert to deliver benefits for consumers and firms alike,

Navy JADC2 Transformation Efforts

The Navy is executing the JADC2 intent as set forth by the Secretary of Defense using authorities and permissions granted by Congress to budget and execute an iterative approach in developing and modernizing C4ISR onto legacy and future platforms within the Service's doctrine of naval operations, distributed maritime operations (DMO). Using a network of manned platforms, unmanned platforms, and ISR aerial platforms, DMO builds redundant lethal capabilities while maximizing domain awareness captured in the DoD's intent for the Navy's C4ISR capabilities to be integrated into the JADC2 vision,

The Navy's Project Overmatch contributes to JADC2, which requires the Iron Triangle's combined efforts, acquisitions, and resources to fulfill multiple Services' strategies. Navy C4ISR accounts for multi-domain platforms, budgetary PoRs, R&D efforts, and combining innovation from private companies within the industry. The Navy's efforts include tackling data sharing, network convergence, software design applications, and partner sharing interoperability. Using existing authorities and guidelines to implement and budget for C4ISR capabilities, the Navy's main challenge with interoperability across the joint forces is acquisition and requirements-based contract writing. The Navy's iterative approach to JADC2 is through force modernization and developing new platforms with new capabilities.

The Navy is first ensuring that all its platforms and shore facilities can communicate and pass data within the fleet as part of a unified integration of data-transformed intelligence supports battle-space awareness via a common operating picture (COP) and common operating intelligence picture (CIP) that enables commanders at all echelons to execute mission objectives through three leading war-fighting C2 platforms, the Maritime Operations Centers (MOC) – in the fleet headquarters, the Carrier Strike Groups (CSG), and the Amphibious Ready Group (ARG). Integrated within the MOC and the CSG are the maritime intelligence operations centers (MIOCs) and the combat information centers (CIC), including a large intelligence cell that fuses

sensor data. Two main C4ISR PoRs connecting the MOCs, CSGs, and ARGs, are the Navy's 1) Global Command and Control System – Maritime (GCCS-M) and 2) the Distributed Command Ground System – Navy and Joint (DCGS-N/J). Two display platform innovations are 1) Talon THRESHER – an Air Force web-based program, and Command and Control Information Environment (C2IE) application – a Joint Staff global integration decision tool. These tools enable the GCCs to visualize data across the joint Services. In 2020, the Joint Staff directed the GCCs to implement C2IE as a COP program for the Services to execute. The challenge is that C2IE and THRESHER are not Navy PORs. Although these programs have been successful for intelligence and operations directorates ashore, the limiting factor is reduced bandwidth on naval ships, submarines, and vessels.

The Navy is operationalizing their respective IT enterprises with the intent to share data across the joint information environment. The DoD's Chief Information Officer (CIO) Directive 8000.01– the Management of the DoD Information Enterprise (DoD IE) outlines technology to enable data throughput, security, and digital Services.[149] The directive also informs the Navy's CIO memo - Strategic Intent for Transition to Naval Enterprises Information Technology Services. The Navy is transitioning from legacy maritime-only IT enterprise networks to a holistic Naval IT enterprise as referenced by the Navy's SECNAV memo - Department of the Navy Actions to Data Advantage, published in June 2021.

An example of an iterative Navy sensor technology in ships is a capability known as the Surface Electronic Warfare Improvement Program (SEWIP), better known as the AN/SLQ-32 Block 2 sensor built by Lockheed Martin. The challenge is that different prime contractors make different versions of the SLQ-32. The Navy is tackling this challenge through software upgrades and innovative new SLQ block designs to unify the data output to legacy ships and systems for analysis within the fleet's command and control centers – on ships and the MOCs. [150] The iterative approach is retrofitting legacy platforms to ensure different SLQ-32 blocks can communicate and pass data across the fleet while simultaneously building the capability via software to push the data to other services once permissions and authorities to operate are in place from the owner of the data.

Providing innovative software C2 applications to the Navy is the responsibility of the software office, known as the Forge. A software factory by design, it is organizationally under the program executive office (PEO) for Integrated Warfare Systems (IWS), where the goal of the factory is to "establish the infrastructure necessary to bring software updates to the fleet's combat systems as fast as a single day."[151] The Forge has been responsive in upgrading software applications on ships known as "Virtual Pilot Ship Increment 1," where the PEO IWS uses open architecture software and hardware to build an "integrated combat system."[152] The challenges of the Navy's organization remain the same in software design as any other technology to be incorporated into the fleet, size, legacy ship modernization, and trust in the software with C2 and combat systems. [153]

The Navy's requirements for integrating cloud technology with data standards that enable joint Service access are owned by the Naval Information Warfare Center (NIWC). NIWC is working on a project called Naval Research & Development Establishment (NR&DE) cloud that leverages Overmatch Software Armory (OSA) networking tools, Amazon Web Services (AWS),

and Azure to develop an infrastructure and gov cloud-hosted environment IAW the Defense Information Systems Agency (DISA).[154] To enable the Navy's NR&DE, NIWC is also working on a communications and networks suite of programs: Consolidated Afloat Network Enterprise Services (CANES), the Automated Digital Network System (ADNS), the Enhanced Polar System (EPS) gateway, and the Mobile User Objective System (MUOS). CANES will provide a shared computing environment. ADNS is a tactical wide area network (WAN) enabling internet-based applications to be shared across the fleet leveraging higher bandwidth satellite communications. EPS gateway supports communications in the polar regions using high elliptical orbit satellites. MOU.S. provides narrowband communications to new and legacy terminals that support highly mobile users. [155] The Navy's acquisitions and contracts need to ensure that the software between these systems is interoperability with the fleet and the U.S. Marine Corp while providing software upgrades for joint Service connectivity.

The Navy's FY23 Presidential Budget (PB) represents a substantive increase in innovation and C4ISR capabilities ranging from the sensors, the shooters, the network, the data, the security, and the R&D to facilitate creation. Much of the Navy's C4ISR budget resides within the OPNAV N2/6 resource office; however, the platforms that incorporate the sensors are within the OPNAV N95-N98 with N9I as the primary integrator for C4ISR resources into platforms. Critical to C4ISR is the Navy's investment in force design (platforms and manpower), R&D, O&M readiness, and facilities that incorporate program elements (PE) of C4ISR within sea and shore platforms. The Navy plans to increase funding in Information Warfare – cyber security, satellite communications, C2 systems, and EW systems, from $2.5B to $2.84B.[156] Unmanned systems will receive a budget increase request from $560M to $966M, representing the requirement for integrating and C2 of autonomous platforms providing sensor packages to support the fleet's DMO.[157] Additionally, classified programs, Science and technology, and Project Overmatch will have a budget increase request from $7.7B to $7.97B.[158] One area that the Navy could improve coordination amongst the requirements is organizationally moving the N2/6 under the N9 for purposes of allocating resources and requirements building. This would support requirements across sensors and platforms.

The Navy is keeping ISR technology and production lines active in budget constraints due to program milestone delays. The Navy is working with Congress and the Departments of State and Commerce to keep the MQ-4 production lines open through foreign military sales to Five-eyes partners. By keeping an open production line, Northrup Grumman can develop parallel ISR and payload capabilities that meet U.S.N requirements while maintaining the production line of the existing platform. Through FMS, Northrup can work on software issues to provide interoperable capabilities and data transfer to and from partners. The MQ-4 Triton program uses much of the same technology as the Broad Area Maritime Surveillance- Demonstrator (BAMS-D) unmanned aerial system (UAS), a variant of the Air Force's Global Hawk and therefore the MQ-4's software and data relay to the AF C2 network will enable the Navy to have future linkage to the USAF's JADC2 effort, ABMS.[159]

As a part of DMO, the Navy is looking to exploit is the technological development of a fleet of UxS as semi and fully autonomous surface, subsurface, and air vehicles. The Navy established an Unmanned Task Force in September 2021 to examine "seven classified spirals aimed at taking specific technologies from industry vendors." During the West 2022 Conference,

an AFCEA established association that brings together military and private industry to align technology and strategy, ADM Michael Gilday advocated that these spirals will enable UxS capabilities to be distributed to the future fleet force design and warfighting doctrine.[160]

The Navy's is taking a UxS Strategic Capabilities Office (SCO) R&D project, Project Overlord, and moving it to a PoR.[161] The Navy's SCO awarded six contract awards for industry studies for prototypes, including the C2 systems and various payloads.[162] These contracts will expire as the program transitions from RDT&E to procurement dollars. The unmanned surface vessel program will reside within OPNAV N96's program portfolio as the Navy looks to industry to build and manage the UxS architecture and processes. As a part of the C2, the Navy examines the capability to integrate private industry software and code into its Rapid Autonomy Integration Lab (RAIL) C2 efforts.[163] The challenge for unmanned C2 and platform technology is allowing the technology to grow and mature. Using a stair-step approach to integrate UxS technology into its IT enterprise, the Navy wants to prove the technology and software works before pushing data to the joint force.[164]

The Navy is taking lessons learned from the United Kingdom's autonomous efforts who have been working on unmanned systems to enhance their limited ship availability by integrating unmanned systems into their fleet using a system called Maritime Autonomous Platform Exploitation (MAPLE). MAPLE is a backbone for UK's unmanned systems to include "C2 consoles, information architecture, communication links and data management systems."[165] The UK's lessons learned have enabled the USN to release an autonomy software suite called 'Odyssey' for the Navy's UxS programs through Huntington Ingalls Industries (HII). Odyssey is an open architecture framework based on the Navy's requirements for an Unmanned Maritime Autonomy Architecture like MAPLE. Duane Fotheringham, an executive at HII, mentions that Odyssey's development is due to "a desire to bring together HII's internal research together with the capabilities the company acquired when it purchased the technology firms Hydroid and Spatial Integrated Systems."[166] The combination of private industry innovation, acquisitions, and engagement with Five-Eyes partners regarding C4ISR open architecture software enriches the USN's ability to share data across manned and unmanned platforms while providing interoperable sensor data to allies.

Appendix F: JADC2 Concept Development and Lessons Learned Assessment

JADC2, Integrated Strategic Deterrence, and Joint Warfighting Concepts

JADC2 as and Integrating Concept Underpinning the JWC. The Joint Staff developed four critical JWC concepts for implementing the new NDS's Integrated Strategic Deterrence (ISD) approach: joint concept for information advantage (JCIA), joint concept for command and control (JCC2), joint concept for fires (JCF), and joint concept for contested logistics (JCCL).[167] Of these four concepts, the JWC concept for information advantage is the primary mechanism to leverage information to direct fires, maneuver, and logistics while denying adversaries' decision dominance. A whole-of-government integration of traditional strategic, conventional, and irregular forces – All-Domain, offensive, defensive, kinetic, non-kinetic, and essential deterrence from agents of other instruments of power will contribute to more robust deterrence and favorable escalation risk management and decision dominance for strategic leadership.[168]

JADC2 enables the future of global command and control from strategic to tactical level by connecting the four concepts supporting the JWC. The JADC2 framework looks to sense, make sense, and disseminate all means of information across the spectrum of needs at the speed of relevance so that commanders can decide and act.[169] This framework connects legacy systems to new and emergent technology and focuses on ensuring a seamless and timely data flow through cloud-based services. Not just a sensor to shooter program, JADC2 attempts to account for all data moving throughout the battlespace. Incorporated into and critical to its success, JADC2 requires advancements in Artificial Intelligence and Machine Learning (AI/ML) to support the understanding, sorting, and storage of the petabytes of data available on the battlefield.[170]

Defining Integrated Strategic Deterrence. With a unifying theory of victory (or success), America's new ISD approach leverages traditional strategic deterrence capabilities, invests in future capabilities, and aligns all other instruments of power to retain decision dominance needed to deter conflict. [171] The ISD approach is intended to remain adaptive and agile by preventing adversarial decision dominance by synchronizing all instruments of power to achieve a common objective in support of the NDS. Deterrence in today's strategic environment requires advancing beyond historic deterrence approaches through denial, punishment, and entanglement when adapting to China or Russia's emerging capabilities. Integrating all instruments of power requires connecting the combined capacity to a focused outcome across agencies that leverage the power.[172] If integration is implemented reactively, the enduring lack of unity of action across the government will make alignment in crisis challenging. Therefore, diplomatic, information, military, and economic (DIME) instruments of national power, must follow a long-term strategy that adapts to the changing operational environment within relatively short windows of time,

Using All Instruments of Power to Deter Conflict. The ISD approach is intended to remain adaptive and agile by preventing adversarial decision dominance by synchronizing all instruments of power to achieve a common theory of victory (or success) in support of the National Security Strategy (NSS). This type of strategic coordination requires the U.S. to build and empower the strategic JADC2 infrastructure needed to communicate across the JIIM agencies.[173] The U.S. government requires refined cross-agency coordination through processes

and technology to leverage DIME capacity within the government. Cross agency information advantage aligned with strategic ends will enable unified and efficient prioritization and resource alignment to promote and protect America's national interests. The ISD approach evolved under the previous two administrations to ensure the U.S. retains its decision dominance needed to deter aggression. Still, it requires synchronization beyond the DoD's efforts to include a whole government approach.

ISD Approach requires JADC2 Capabilities. Leveraging all instruments of power in the DoD's implementation of the ISD has two critical gaps required to prevail and deter future conflicts.[174] Developing and employing a practical ISD approach requires a new common JADC2-like infrastructure that connects strategic policy across the government with the authorities and processes that align agents of all instruments of power and a long-term grand strategy as an organizing principle for action. The central problem with today's strategic environment is the risks of "perceived erosion of America's deterrence, which invites opportunistic adventuresome that is inimical to U.S. core interests."[175] American military power grew more dependent on niche technologies and advanced processing systems to mitigate the lack of people and raw firepower. The nation's capacity to conduct large-scale conflict that integrated the entire federal government, the defense industrial base, and the private sector atrophied for extended periods.

JTRS Lessons Learned for JADC2 Implementation

While JADC2 is viewed by many as a new and innovative concept, we must be aware of similar and parallel historical efforts and apply the lessons learned to JACDC2. The Joint Tactical Radio System (JTRS) was the last Joint sensor for the shooter program. JTRS intended to reduce and replace the multitude of radio systems within the DoD used by the military to permit seamless operational communications for C2 through all levels of command, including direct access to information from airborne and battlefield sensors.[176] Even JTRS failed to learn critical lessons from its predecessor of only a few years, the SPEAKeasy radio, regarding the difficulties associated with the size and weight constraints, obtaining National Security Agency certification, and developing a multi-channel JTRS-approved software-defined radio. With a decade passing since the JTRS Joint Program Office officially closed, the DoD should be reviewing the lessons learned from one of DoD's most infamous failed Joint programs as we surge into JADC2. Without understanding the successes and failures of the past, we cannot hope to avoid similar pitfalls and capitalize on lessons learned as we move forward.

Requirements. Joint programs usually establish a new Joint warfighting capability, improve Joint interoperability, reduce duplicative efforts, reduce total development and production costs, and standardize logistics requirements. However, Joint programs do not always work. As the JTRS program evolved, the reality of each Service's unique requirements emerged. Services focused on their specific capabilities. Services began to back out of the Joint effort when the program office solutions did not meet their requirements. JTRS aimed for overarching standards across the Services, but the program office never achieved this vision. As with most traditional large acquisition programs, JTRS requirements were overly prescriptive. The capability managers designed the requirements to rationalize industry hardware and government-owned waveforms and network management tools, which did not focus on the capability requirement.[177] The requirements focused on providing capabilities with very strict parameters. This approach does not allow any flexibility and sets the program up for failure if any single

element fails to achieve its threshold requirements in line with the rest of the program. The prescriptive JTRS requirements documents did not provide the flexibility required for the increased evolution of modern technology. Moore's law claims the quantity of transistors in a dense integrated circuit doubles roughly every two years.

Soldier Involvement. As the official Soldier representatives, the capability managers must involve themselves early. The operational users must also be involved early and consistently throughout development and testing efforts. JTRS programs never included significant operational user representation until the operational test, a defined test and evaluation requirement. The program office conducted small Soldier touchpoints with Special Operations Forces elements, providing helpful feedback. However, the SOF units are not representative of the primary user of the equipment in scale, use, or operator experience. Early and often interactions are essential to providing accurate and timely input and feedback for JADC2 hardware, software, and doctrine, organization, training, materiel, leadership and education, personnel, and facilities (DOTMLPF) impacts. JADC2 efforts must provide the willingness and the leniency to fail early. The JADC2 model is touting early Soldier touchpoints and letting industry provide solutions without long government-provided developmental efforts. These ideas are not new concepts, even within the DoD. The Army established the Army Warfighting Assessment (AWA) in 2011 using the Brigade Modernization Command (BMC) to assess Warfighting Challenges by injecting innovative concepts and capabilities into Joint and Multinational formations. The AWAs aimed to accelerate the rate of innovation and enhance training, Joint and Multinational interoperability, and future force development. While the AWA was retitled the Joint Warfighting Assessment (JWA) in 2017 and the command was redesignated the Joint Modernization Command (JMC), the mission has not changed significantly.

"Perfect" versus "Good Enough." JTRS chased the "perfect" solutions rather than focusing more on defining material solutions that were "good enough." The traditional acquisition process mandates developmental and operational testing of each key performance parameter (KPP) and key system attribute (KSA) within the overly prescriptive requirements document. JCIDS requirements documents assign threshold and objective values to each KPP and KSA. The threshold value is considered the minimum acceptable level of performance, and anything below the threshold is not operationally effective or suitable. While KSAs are considered important, KPPs are considered critical to the operational capability, and failure to meet the threshold requirement can lead to program modification or failure.[178] Care and analysis must determine threshold values that allow better capability than the warfighter currently has at their disposal. Trade space, the delta between the threshold and objective values, allows incremental improvement as technology and production processes improve. Poor initial analysis can lead to unattainable threshold values and the potential to eliminate the opportunity for increased capacity to reach operational Soldiers. The DoD and the Services must avoid chasing the "perfect" solution and focus more on defining material solutions that are "good enough." If there is one thing that JTRS operational feedback has consistently provided, each commander prefers different types and amounts of data. This answer is not ideal since the network design and performance directly reflect the amount of data required and where the data is coming originates. The Services must establish a bare minimum range of data echelon commanders require for mission success. Commanders must be able to access the data needed to ensure the

best chance of mission success. However, commanders must still employ mission command and avoid over-saturation of data and the temptation to use data to micromanage the fight.

JTRS Architecture and Engineering Design. JTRS engineers designed a system of systems (SoS) architecture, which means each system is part of a more extensive whole systems architecture where each system depends on the others for the SoS to work as designed. The SoS architecture relied on hardware and software products to make the system work as intended. SoS architecture works well when the DoD can develop and field all systems in parallel. However, limited Soldier capability resulted due to a lack of synchronization across the various systems regarding development, testing, and fielding. JTRS contained five program offices, and none of them were in synch. Even worse, once the DoD began to terminate some programs, the capability gaps associated with the terminated programs became exposed within the JTRS SoS architecture.

Networks require hardware and software tools to provide management and monitor capabilities. JTRS included both government-designed waveforms and network management tools. Unfortunately, the supporting network management tools lagged in development compared to the schedule of the JTRS radio solutions. The radio programs mitigated risk by developing independent low-cost network management tools as a bridging solution. The test community viewed each JTRS program as an SoS, and the test reports reflected the failures of the temporary network management tools. For any JADC2 function or increment to claim success, the Warfighters must receive everything required to make that capability function as intended.

JADC2 must design a transport agnostic architecture not reliant on specific hardware or platforms. Incremental additions and changes must deploy to the operational force at the speed of relevance. The design must rely on open systems architecture, allowing the addition of hardware systems and software without dependence on other systems. Each service owns multiple data fabrics and development, security, and operations (DevSecOps) environments. Policy and authorities notwithstanding, DoD focus on establishing common standards for data fabric and APIs provides the services the flexibility needed for developing their unique networks while continuing to increase accessibility and usability of data across services.

Electromagnetic Spectrum. JTRS design required the use of a limited and hard to acquire spectrum. The JTRS design required heavy use of the Ultra High Frequency (UHF) and L-band spectrums. UHF and L-band allow for optimization of data throughput and transport range. The main issue for DoD is that this portion of the EMS is also used heavily in the commercial sector for cell phones, broadcasting, satellite communications, Global Positioning System, Wi-fi, Bluetooth, and more. Spectrum challenges were known, but a conscious decision drove specific spectrum requirements within the JTRS requirements documents. Effective, suitable, and survivable voice and data networks require the flexibility of operational usage across the electromagnetic spectrum (EMS). Accessing all portions of the EMS is more crucial than ever due to the increased amount of data the DoD is creating and transporting over the network and the current threat jamming capabilities. Spectrum availability is increasingly complex to secure based on ownership and location. The federal government analyzes spectrum to control at the federal level versus chunks of spectrum auctioned to the commercial sector. Additionally, every country manages its spectrum within its sovereign borders, and the U.S. must operate within the parameters established with the home country. Spectrum challenges will continue to get increasingly challenging, but DoD must conduct in-depth analysis and establish international

agreements early on. Any spectrum requirements the DoD cannot secure within the United States or other host countries should strongly influence the acquisition path for expensive end items since lack of operational spectrum hinders the ability to train as we fight. The DoD must consider the spectrum impacts in all JADC2 discussions and the pros, cons, and authorities for spectrum use.

Electromagnetic Signature. Due to current threat capabilities, there is an increased awareness of the electromagnetic signature produced by operational units. JTRS successfully contributed to a sizeable electromagnetic signature for every operational unit, platform, and Soldier running one of their mobile ad-hoc network (MANET) waveforms, which are constantly active on the network. Based on the adversarial analysis from the wars in Iraq and Afghanistan, the U.S. continued to develop and field new capabilities with little to no regard for the electronic signature tied to each Soldier, platform, or unit created as they operated and maneuvered through each area of operation. Moving into JADC2, the DoD and individual Services must consider the risk associated with all additional capabilities based on the electronic signature tied to each versus the added capability.

AWS Lessons Learned for JADC2

Both JADC2 and AWS are frameworks that do not offer a single right answer. Each has unique considerations for complex and adaptive environments with strong cultural influences within their organizations to innovate quickly and mitigate the risk necessary to maintain relevance. For DoD, the ability to implement a JADC2 framework that supports innovative advances requires a sense of urgency, strong leadership with the delegation of authorities, an honest risk assessment, and a re-consideration of branding and communication to force multiple dilemmas on adversaries. While national security requirements and goals may diverge from the profit margins of the commercial sector, there are many stakeholders and use cases, such as Amazon and others across industry, to advise on military innovation. Understanding these stories and learning from case study analysis can inform a more integrated military and ultimately a more agile defense base to meet future national security challenges.

Lessons from Empowering Internal Innovation. Since its inception, Amazon.com has pursued relentless online sales and services expansion. However, despite aggressive initial growth the dot-com crash in 2000 was a devastating blow for most Internet companies, including Amazon. They were in dire financial straits and near bankruptcy. Stock prices fell from $100 to $5 a share, and founder Jeff Bezos was challenged to regain market capital.[179] He turned to Andrew Jassey, a trusted employee who was working with Bezos in a "shadow" or Chief of Staff role, and charged him with accelerating the long lead times for projects so that the company could recover.[180] Jassey discovered internal delays due to entangled features on the original retail development platform. Engineering solutions did not scale, and redundant efforts ran rampant across the departments. He hand-picked a team of the best tech minds and product developers from across the company and started with the third-party seller Merchant.com as the test case to decouple customer data and share it across the organization through well-documented Application Programming Interfaces (APIs).[181] The team reflected Amazon's balance of direct vs. indirect ratios of experts to managers and created their internal customers through iterative approaches to gain efficiency. They realized that the challenges they encountered in communication, data sharing, and efficiencies were likely not unique to Amazon,

Working Backwards Approach to Develop Intrapreneurship. Following the "Working Backwards" methodology, the team drafted an Amazon "6 pagers", a narrative pitch for new ideas describing marketing strategy and including anticipated press questions.[182] The business vision and plan described the same enterprise service needs like cloud computing, storage, and programmed process integration that Amazon would sell to other organizations they imagined were facing similar challenges. The plan mirrored Amazon's cultural and leadership principles, making it easy for all stakeholders, from executives to coding programmers, to understand the end state. Unlike many technology companies that create a minimum viable product, the consistency of the reverse approach was further validated by internal use cases. AWS created an organic customer from Amazon's own departments to act as the first mover for new technology solutions. AWS teams gained experience and created value by quickly iterating based on candid feedback, then aggressively pursuing the next milestone to avoid getting stuck with primitive prototypes. Budgets, costs, and investments were not considered heavily in the initial phases, favoring short-term risk over long-term payoff. Jassey explained that Amazon's understanding of high-volume goals that develop over time contributed to the investment in capital needed to take bold but calculated risk.[183]Jassey kept the team focused on the vision for the overall market, not necessarily one product, and remained vigilant to seek initial external customers such as startups who could take risks and become viral advocates within smaller segments. The deliberate build of the customer base, along with evangelical marketing roadshows where Amazon executives, armed with scripts and use cases to advertise successful services, created momentum that grew organically. Furrier describes, "AWS wasn't any one person's single idea. No proverbial apple fell…instead it rather emerged. The idea grew out of the company's frustration with its ability to launch new products and support customers…born as a startup within a large company. Arguably the best intrapreneurship venture of our time".[184] Intrapreneurship is a critical idea from AWS case study that can inform the DoD's JADC2 implementation, especially as the framework also originated from an internal effort to solve common issues that were common across the organization.

Parallels between AWS and JADC2. As a comparison case to Amazon Web Services, the Joint All Domain Command and Control framework is presented for consideration. JADC2 is defined in the 2022 implementation strategy as "The warfighting capability to sense, make sense, and act at all levels and phases of war, across all domains, and with partners, to deliver information advantage at the speed of relevance."[185] The concept emerged from an Air Force proposal for requirements to pursue interoperable capabilities in support of Multi-Domain Operations (MDO), that was embraced and then elevated to the Joint Staff to achieve All Domain solutions across all the Services. The end state is to provide a technical framework that connects the Joint Warfighting Concept and improves decision cycles with increased speed, range, and convergence of capabilities, Historical attempts at similar integration efforts across the military include programs like Future Combat Systems, Joint Tactical Radio Systems, Network Centric Warfare, among others, Generations of leaders have spearheaded efforts, programs, campaigns, and concepts with few viable joint solutions, However, the JADC2 approach has been met with renewed emphasis, endorsement, and resourcing, In 2019, a Cross-Functional Team (CFT) was established under the J6 to synchronize and integrate efforts across the Services.[186] Starting with the combatant commands' integrated priority lists, the CFT drafted a crosswalk of tasks and milestones that was processed through the Joint Requirements Oversight Council and signed by the Deputy Secretary of Defense. The JADC2 implementation strategy was released in 2022 and articulates the Department of Defense approach for advancing

the capabilities necessary to gain and maintain information advantage and support national security interests.[187] Several examples of JADC2 concepts emerged during the publication process including COVID mitigation, the Afghanistan Non-Combatant Evacuation of the Kabul embassy, and the military's Ukraine response, Each situation reinforced the importance of immediate, authoritative data sources to deliver relevant and timely information for decisions at all levels of command, The concept of sensor-to-shooter communication was refined to encompass information dominance and decision advantage, Data centric environments provide opportunities to incorporate both disruptive and emerging technologies such as Artificial Intelligence and Machine Learning, 5G, and quantum computing, as well as fundamental concepts like behavior-based analytics, security principles, cloud computing, electromagnetic warfare, and robust transport, Compared to platform or network centric approaches of the past, implementation of JADC2 is focused on data.

Mobilizing AWS-like Intrapreneurship for JADC2. Three years after the formation of the JADC2 CFT, each Service has pursued their own initiatives to support the concepts, However, as one senior leader explained, the challenge remains the culture and authorities to first, buy down the technical debt on legacy systems, and then to innovate with open architecture across all domains and Services.[188] JADC2 efforts have engaged a broad and diverse range of stakeholders across government, industry, allies, and partners. The U.S. DIB has a proven track record of innovation and talent but is struggling to find a unified effort to implement the JADC2 framework, America's Great Power Competitors in the "Everything War", especially China, appear to also be keenly focused on integration challenges with deep civil-military fusion that drives their advancements in capabilities and technology, While there is perceived success in these models, the U.S. is committed to democratic values and will continue to drive progress that ensures integrity as well as security. Industry case studies of American companies such as Amazon can provide insight into how DoD leadership can achieve the JADC2 vision, The following section answers the Key Essential Questions (KEQ) posed for this organizational analysis.

Focus on Innovating Internal Communication. Survival following the dot-com crash drove Amazon to make internal changes resulting in not only recovery, but the creation of Amazon Web Services that supported the health of other organizations facing similar challenges, The U.S. military faces much different ultimatums, but a similar sense of urgency in pursuing JADC2, While the DoD does not necessarily fear bankruptcy, there is the obligation to secure the nation against emerging and uncertain future threats, Both Amazon and the military share a common motivation of not only relevancy by meeting future challenges, both are committed to dominating their respective competitive spaces, American organizations value global influence and responsible leadership.

Developing Innovating Processes and Performance. AWS's approach is multi-faceted with component attributes that may support JADC2 efforts.

Leadership/Authorities. Amazon founder Jeff Bezos has been described as an autocratic leader who played multiple roles (liaison, spokesperson, negotiator, etc) to serve his company during his tenure from 1994-2021.[189] While his style may not have been preferred by all employees, the value of the company and growth of the brand cannot be discounted, As a CEO, Bezos relied on data and metrics as much as his gut and experience, Military senior leaders are equally invested in their careers of service, JADC2 seeks to introduce additional inputs for data

informed military decision making. The U.S. military culture may not necessarily grow, nor even tolerate, a polarizing personality like Bezos, but the manner in which he exercised corporate authority is worthy of note, The DoD is a monolithic bureaucracy that happens to employ extremely talented and forward-thinking individuals who build strong teams, Individual budgets drive priorities and actions because those with the money get the vote, Many military innovations have succeeded in pockets of chaos, but those that ascend to institutionalization are those that understand authorities and bureaucracy, JADC2, like AWS, must demonstrate this understanding and remain aligned with corporate and professional values.

Workforce/Structure. Leadership is defined by workforce. Accordingly, Amazon leadership defines itself as a technology company and therefore favors "direct" subject matter experts such as engineers, coders, and programmers to build the bulk of their project teams. Managers and supervisors are "indirect"; valued talent but balanced to reduce administrative overhead, The success of AWS and other Amazon initiatives is attributed to the talent and commitment of the employees and teams, JADC2 shares a technical nature and should consider the expertise of individuals who have deciding votes on investments and initiatives.

Promote Intra vs Entrepreneurship, Amazon Web Services was described as the ultimate intrapreneurship among its market competitors.[190] The leadership's self-awareness and agility to rebuild internally was a key factor in the company's survival through challenging conditions, Solving one's own problems is a valuable skill and most organizations have an innate tendency to protect their people, processes, and property. The airline emergency analogy makes sense: fix yourself first, then assist others, Natural proprietary concerns must be balanced against the need to provide transparency in order to connect with partners, stakeholders, and networks that can deliver new ideas without sacrificing sensitive information. The DoD struggles with the make versus buy dilemma, especially when it comes to technology solutions for JADC2 concepts, Despite a rich pool of talent throughout the ranks and Services, the hierarchical structure of the military makes it difficult to quickly task organize for purpose at a strategic level, Industry critics advise the government to trust that existing solutions were developed for a purpose, Military problems may not be as unique or extreme as leaders may assume, especially when it comes to security, and therefore, a simple adaptation may advance a product into dual use.[191]

Communication as a Strategic Asset for Innovation. Amazon's "Working Backwards" philosophy is a powerful concept for ensuring shared understanding of emerging concepts across the organization, The description of the AWS six-page business proposal does mirror the similar JADC2 endorsed implementation strategy, however, there remains a disconnect in generating a shared understanding of the concept at all levels in the military. Branding, including naming conventions, are important. Before Bezos formally named Amazon after the world's largest river, he registered several other domains including Cadabra (sounded too much like cadaver), and Relentless.com, Words have meaning and acronyms like JADC2 may not provoke the same powerful imagery. Every Service has different project names related to the JADC2 framework, all either acronyms or buzzwords, Industry has even introduced additional nomenclature in an effort to capture their individual contributions.[192] The fact that a unifying concept with an implementation document still requires additional products to augment, complement, and translate the strategy may be an indicator of a lack of shared understanding. The DoD may explore a re-branding of the JADC2 framework as it matures to ensure that all stakeholders understand the origin story and collective end state.

Applying Lessons Learned to JADC2 Implementation

Joint Tactical Radio System (JTRS) Offers Insights for JADC2 Challenges Ahead

The JTRS acquisition strategy provided built-in competition.[193] The JTRS programs began with dual vendor solutions designed to compete individually for production contracts. While this approach allowed competition, it also limited competition and made it more difficult for new vendors to compete. The JTRS schedule delays led to acquiring tens of thousands of commercial-off-the-shelf (COTS) radios from to act as a temporary bridging solution until JTRS was ready to field. The most notable procurement of a radio bridging solution involved a sixty-three-million-dollar order for sixteen thousand AN/PRC-117G radios from Harris Corporation using an existing General Services Administration (GSA) contract.[194] The Army procured COTS radios based on operational needs statements (ONS), which meant none of the COTS radios underwent the rigorous testing required of an acquisition category (ACAT) 1 program, which mandates the highest oversight. The Handheld, Manpack, and Small Form Fit (HMS) radio program, one of the last remaining JTRS programs, received an approved Milestone (MS) C decision in June 2011.[195] A MS C decision authorizes a program to proceed to the production and deployment phase of the Defense Acquisition System.[196] However, the Army only authorized multiple procurements of low-rate initial production (LRIP) quantities until the HMS program finally received a full-rate production (FRP) decision in September 2021 authorizing the entire required procurement of radios and the services.[197] The decade-long delay between MS C and FRP sent powerful messages of concern to industry regarding the stability of requirements and DoD's funding commitment.

Feedback from industry stresses the need for consistent requirements messaging and available resourcing.[198] Due to the varying requirements and acquisition approaches like JTRS, big industry is displaying reluctance to invest their IRAD dollars for JADC2 efforts without identified resourcing or validated requirements.[199] Annual IRAD resourcing is limited, so companies tend to fund efforts that will yield the most significant future gains. Industry needs better direction from the DoD to guide their research and development investments. Validated requirements provide the least risk for industry to invest in IRAD. Companies must also see DoD providing contracts to award research and development efforts. Large amounts of investments and experimentation efforts that do not lead to contracts cause industry to become more risk-averse towards future efforts.[200]

JADC2 Lessons from a Case Study of Amazon Web Services.

A cross-disciplinary AWS case study offers lessons for the DoD's efforts to implement JADC2. AWS success among intense rivalry and dynamic market conditions holds industry wide application pertinent to multiple industries, including the DoD.[201] DoD is facing a similar inflection point with integrating decision making with the 2019 launch of the JADC2 framework. There are deep comparisons to AWS's "Everything Store" to the DoD's "Everything War" as it pertains to an organizational analysis of Amazon and the Department of Defense in their ability to innovate, DoD's JADC2 strategy and implementation can apply lessons learned from Amazon.com, Inc.'s experience creating Amazon Web Services in order to communicate internally, establish efficient processes, and support a culture of innovation within existing and future systems to support the most informed decision making for national defense.

Appendix G: JADC2 Communication and Culture Assessment

Implementing a JADC2 Education Strategy

The JADC2 team should set a target for military education for DoD, international, interagency, and industry partners, It would likely be a phased approach, informed by both the JADC2 Implementation Plan and JWC, is suggested to first inform at an unclassified level with increased emphasis on data fluency or data literacy, Once this unclassified strategy is implemented, subsequent iterations should provide classified JADC2 U.S. and critical adversarial capabilities. The current Implementation Plan specifies that JADC2 be incorporated into all PME programs. However, little detail exists as to how this is to be accomplished. The likely outcome would be a disaggregated and disjointed effort with inconsistent training across Services. If the JADC2 framework is one of DoD's top priorities, greater emphasis should focus on infusion into additional academic programs that strengthen student and faculty understanding, The United States Air Force Academy, Officer Training/Candidate School (OTS/OCS), Reserve Officer Training Corps (ROTC), and enlisted technical schools are key institutions to begin JADC2 exposure, Joint roadshows, course objectives from the Air Force's Multi-Domain Officer (MDO) course, and undergraduate joint exercises represent chances to instill a JADC2 mindset.

JADC2 Joint Roadshows. Current JADC2 roadshows are Service-centric events consisting primarily of Service JADC2 contributions, Last year, Air Force JADC2 leads provided an ABMS overview to field grade officers and civilians at the Air Command and Staff College (ACSC) in Maxwell, Alabama.[202] Speakers highlighted ABMS, the Air Force's contribution that focuses on development, security, and operations (DevSecOps), specifically using cloud environments to improve the speed of data to decision-makers through automation, autonomous machine learning, and human-machine teaming.[203] Experts raised tough questions to expose students to the future of warfare, but ABMS dominated any discussion of joint projects. The goal should be to emphasize how organizations have been or are striving to be JADC2 relevant, recognizing individual interoperability and interconnectedness may produce redundancy necessary for joint integration, Each audience should comprehend that the Navy's Project Overmatch pursues naval operational architecture to ensure tactical forces can fight through mission distributed operations.[204] Students should also understand Army's investment in capabilities to integrate legacy and future technologies to increase decision speed from sensor to shooter in Project Convergence.[205] This diverse perspective will complement additional objectives: kill chain concerns, JADC2 background, CFT intent, enabling technologies, LOEs, and JADC2 alignment to the JWC priorities, A total site picture will ensure students appreciate how stakeholders work first to achieve the internal strengths necessary for JADC2 operations. Congressional funding, policy, and authority discussions should serve as a final objective, Since FY17, the DoD has spent an estimated $22.5 billion on JADC2, resulting in Congress wondering what there is to show for it.[206] Congress funds programs of record consisting of platforms, weapon systems, or components through clearly articulated requirements, not webs of technological advancements. JADC2 is not a platform but a mindset to provide a mental framework for how requirements should center around information sharing, These solutions stretch across various platforms, weapon systems, components, or software infrastructure making it difficult to articulate overarching JADC2 requirements. This level of Congressional uncertainty has led to funding cuts to projects such as ABMS. In addition to Congressional

concerns, all need to understand policy and authority discussions surrounding the implementation of emerging technologies in warfare. Policy, doctrine, and authority will have to evolve. Educating the most junior members will only help inform senior leaders working on these highly contested issues, Junior members are the most data-savvy members open to AI and machine learning. Understanding current concerns, these members may have ideas to contribute as they see the world differently than most senior leaders who need new perspectives to enhance their views and operational experience.

Infusion into Military Strategic Studies & PME. JADC2 should be the next course objective infused into military strategic studies at all Service academies. For example, incorporating applicable multi-domain officer command and control curriculum into strategy classes will amplify individual contributions to the joint fight. In February 2022, the Chief of Staff of the Air Force canceled the career field, emphasizing the material, skill set, and knowledge base should be assets possessed by all operators to enhance the joint environment.[207] While some material is in PME, applicable lessons should be added to commissioning sources and technical schools to improve joint operations effectiveness. Following early education, JADC2 objectives are necessary at all PME levels, PME is a unique opportunity for U.S. military (Active Duty, Guard, and Reserve), civilian, interagency, industry, and international partners to learn and collaborate. Adding JADC2 to military history or warfare courses will solidify this operational concept as the next evolution in military warfare. Once a JADC2 curriculum is normalized across educational institutions, exercises will improve confidence in JADC2 operations that aim to complicate the adversary's kill chain.

Service Academy Joint Exercises. JADC2 exercises are crucial to producing the best operational outcome. Service academies provide various summer programs to prepare and build students' operational prowess. Therefore, senior leaders could direct a new joint exercise program to challenge the Service academies' top students just before their senior year. To improve joint execution, the exercise would prioritize information sharing to execute the best decision with the best weapon system, regardless of Service, while remaining aligned to commander's intent, especially when communication is limited as with mission command operations. Data analysis is critical to exercise and operational success. Therefore, Service academies are beginning to invest in programs to produce digitally intelligent operators, Programs such as the Udemy Digital University or DataCamp will ensure the newest generation can process the right data quickly and effectively, Whether by human or autonomous technology, data and decisions are central to JADC2. This prioritized investment will give students the understanding necessary to execute actions such as targeting decisions in exercises or future warfare. Now, military Services such as the U.S. Space Force invest in data fluency training to build trust in handling, analyzing, and disseminating the right data to make the right decisions.[208] Along with data fluency, academic undergraduate programs such as those from the University of Texas Austin (UTA), a University Affiliated Research Center (UARC), could augment Service academy joint exercises in two ways, Currently, UTA executes two education models that could be beneficial in producing leaders to remain curious and not judgmental about JADC2: Hacking the Defense course and the Clements Center for National Security. Both programs challenge students with pivotal national security concerns and policy challenges to cultivate innovative, strategic solutions at the lowest levels.[209] Therefore, partnering these programs with Service academy exercises would challenge students with ambitious national defense scenarios such as human-machine teaming that would present trust and risk challenges in operational decisions.

Additionally, civilian students should participate in these joint exercises as many will pursue careers in national security. Forging early relationships could result in a more cohesive national security enterprise necessary to navigate the future JADC2 environment.

Senior Leader Education. Until JADC2, in all its definitions, becomes well-known and institutionalized, senior leaders also require education. Additional objectives must focus on trust, credibility, and accountability where the joint and combined unity of effort and decision-making is more important than individual Service outcomes. A JADC2 education must evolve into the general and flag officers (GOFO) ranks to solidify integration and collaboration, specifically in CAPSTONE and future Joint warfighting courses. During the six-week CAPSTONE, newly selected GOFOs prepare for the next leadership level to become "more effective in planning and employing U.S. forces in joint and combined operations."[210] Objectives cover military-civilian relations, understanding the Command Senior Enlisted Leader relationship, and a summary of a recent global military integration exercise focused on globally integrated operations to "enable senior leader decision making in support of the National Defense Strategy."[211] While the executive summary mentions terms like force design and force management, there is no mention of JADC2 or terms like data, speed of relevance, or mission command. Operating in a decentralized, mission-command environment requires trust from senior leaders that their subordinates understand and will execute actions within their intent. Yet, if senior leaders are not challenged with these scenarios, they may not be as prepared as they could be for the future warfighting environment. For continuing GOFOs, the LeMay Center provides instruction such as the Joint Flag Officer Warfighting Course. In this course, GOFOs study "warfighting, synchronization of interagency operations, military doctrine, and the application of unified, joint, and combined combat forces."[212] Again, a JADC2 mindset is implied in these objectives but not explicitly highlighted, ensuring senior GOFOs understand their role in synchronizing operations in the JADC2 environment. GOFOs use their talent and experience to always remain two steps ahead with their vision. Asking defense industry partners like Boeing and Northrup Grumman to present their JADC2 research may enhance their vision. Despite the lack of government requirements, these defense industry companies are leaning forward and investing IRAD into JADC2 technologies and vignettes.[213][214] This discussion may stimulate the identification of new requirements that subordinates and Congress can comprehend because GOFOs can now visualize new synchronization of efforts in future warfare.

Training Strategy – Operator to Senior Leader. Training occurs for members to understand and execute their role for mission success. Integrating JADC2 objectives into individual or recurring programs may optimize individual impact for organizational success. Building on the JADC2 IPlan, training objectives should include JADC2 roadshow topics, data fluency, and cyber security computer-based training (CBT) over the next five years, Additionally, all positional training should address how individual actions align under the sense, make sense, or act construct. Members should then practice through JADC2-focused objectives in recurring joint, Combatant Command, international, or Service exercises. Moreover, while some Services are now beginning education with industry, interagency, and Federal Funded Research and Development Centers (FFRDC), these opportunities should be prioritized across the Services. Finally, consistent leadership messaging, advocacy, and recognition are pivotal in reinforcing a JADC2 mindset.

JADC2 CBTs, Exercises, & Exchange Opportunities. JADC2 CBTs are a consistent way to reach all stakeholders. This training should consist of the Joint Roadshow objectives

underpinned by the JWC and JADC2 CFT strategy, provide deeper emergent technologies discussions, emphasize industry and international contributions, and leverage various programs to build digital intelligence. Awareness of AI, machine learning, autonomy, and automation must be a top objective. To foster trust, all need to see how these technologies are already influencing daily lives. Occasional mishaps highlight risks, but the time-saving benefits from machines handling human tasks outweigh the risk. Next, understanding industry and international contributions will help operators articulate JADC2-informed requirements focused on information sharing to optimize integration, Finally, along with previously discussed data programs, Amazon Web Services' free data-based tutorials should be considered periodic training requirements to create digital excellence and confidence.[215] These CBTs and data training serve as a JADC2 foundational baseline to influence positional training programs and recurring exercise execution across all levels. Operators will better analyze and trust data, make informed decisions, and integrate with all stakeholders. Additionally, planners can design exercises that expose operators to the various ways the human is in or around the loop. Ultimately, humans are responsible for decisions, but operators need to practice human-machine and autonomous technology scenarios. New objectives could be formulated that challenge the kill chain prosecution in unconventional ways, perhaps executing steps in different orders due to the benefits of machine teaming.[216] Being challenged in CBTs and exercises will not be enough. Exposure to diverse business and operational perspectives is equally important. Today, incentivized educational exchanges occur with the defense industry, FFRDCs, and government labs. Similar opportunities with commercial companies like Amazon, Microsoft, or Google would further strengthen relationships and enrich data literacy skills. Additionally, organizations like the Army Futures Command Software Factory could consider possible mid-level officer and enlisted internships. Exposure to rank agnostic software operations would showcase JADC2 mindsets in action and allow leaders to watch and learn from all to more effectively lead their teams.[217]

Senior Leader Engagement. JADC2 requires credibility and accountability to become normalized. Senior leaders must take advantage of every opportunity to teach and inspire trust in the JADC2 framework. Highlighting JADC2 accomplishments, applauding decisions over outcomes, and recognizing the importance of taking risks will show that leaders think differently and expect the same from their subordinates. To reinforce the consistent messaging, the JS J6 should produce a one-page JADC2 cheat sheet that focuses on the importance of integration and information sharing. This cheat sheet should be distributed during visits to PME institutions, technical schools, commissioning sources, industry, international, interagency, and international organizations. Additionally, senior leaders should examine new, innovative methods to reinforce JADC2. To emphasize DoD intent, the JS should investigate partnering with Hollywood's MasterClass creators to formulate a digital JADC2 training program. MasterClass is an online experience that facilitates learning across several topic areas utilizing film quality capabilities in delivering instruction from experts.[218] Sessions and series can range in length with multiple instructors. Therefore, by leveraging Hollywood experience, senior leaders will have a new, more entertaining method to reinforce JADC2 intent and solidify a prominent new mindset.

Communication Strategy for JADC2

Communicating through change is difficult regardless of the size of an organization. Along with bringing forward a new idea comes the challenge of developing a new language to power what is usually a novel vision. It is often difficult to strike the right balance between the natural uncertainties of "newness" without compromising the idea's credibility or that of the organization. For the DoD, this task becomes more difficult given the overarching defense culture and the exacting expectations of the external stakeholders who influence the process of change. This tension has never been more evident than during the force's most recent modernization efforts. Articulating the purpose and vision of the JADC2 framework is one remarkable example of this challenge.

Assessment of JADC2 Communication and Culture. In 2020, the Department released the JADC2 Vision, followed by the Strategy and Implementation Plan in 2022. These documents intended to clarify the definition of JADC2, introducing it as a concept that undergirds the way the force operates in an "increasingly information-focused warfighting environment."[219] The public release of this strategy raised more questions than it did answers.[220] Touchpoints with industry, academia, and defense organizations revealed that stakeholders within and outside the DoD still struggle to understand what the Department is trying to achieve. The DoD must develop a lexicon and unity of effort to bring JADC2 into fruition.

Each Service invested enormous energy into exploring technology, policy, and changes to force structure to develop their view of the force of the future. This period launched significant force modernization efforts to include Project Convergence, Project Overmatch, and ABMS. Each project now serves as the test and demonstration milestones for the JADC2 Joint Integration Concept. However, the utility of vague language has run its course. It threatens the Department's ability to create the unity of effort needed to move JADC2 from concept to reality. Having unified communication strategies to develop a precise lexicon is critical as the DoD enters the JADC2 implementation phase. This paper explores the two critical communication gaps that prevent the DoD from reaching a unity of effort and recommendations to integrate into communication strategy development designed to maintain the forward momentum needed to bring JADC2 into fruition.

Digital Natives vs. Digital Immigrants -The Generational Divide. Educator Marc Prensky coined the term digital native to describe people who comfortably operate in the digital space. In contrast, digital immigrants represent a generation that adapted to the digital technology boom with varying degrees of success.[221] The distinctions between the two groups describe the level of comfort with technology that each group has and indicates a difference in how each group deliberates processes, problem-solving, and communication. While Prensky wrote about educators bridging the gap between teaching tradition and educational necessity, the challenges that once resided in the classroom are now at play in the boardrooms where the DoD and their stakeholders attempt to develop the shared understanding needed to advance both the technology and culture objectives of JADC2.

Communication and Interservice Rivalries – The Purple Divide. The Army People Strategy defines Service culture as "the foundational values, beliefs, and behaviors that drive an organization's social environment, and it plays a vital role in mission accomplishment."[222] Service culture manifests itself through language that creates a shared understanding and unified effort. The Warrior Ethos, the Airman's Creed, and the Marine Corps Code of Ethics are all artifacts that demonstrate this. At the most basic levels, Service culture defines how the force views itself and helps create a shared understanding for members therein. At the highest levels, culture drives how others view the Service and how each respective Service competes for recruitment and resourcing. In other words, each Service rallies around the brand. This strong sense of self often results in a level of protectionism that creates a horizontal communication barrier that complicates developing buy-in for ideas that originate outside of the force. This barrier applies to how Services resource and how they engage with elements outside of their group.

Figure 9: Service Culture Model (source: Willow Management Company)[223]

The DoD has traditionally leveraged compliance culture to break into respective communication siloes. The publication of policies, orders, and Joint strategies aims to create synergy across the purple divide. At best, they provide baseline guidance that each Service uses to create respective programs. Rarely does this top-down communication approach accomplish synergy across the Services to make truly integrated efforts. In other words, a compliance culture creates joint operations instead of joint integration. The JADC2 framework requires joint integration and fusion of multiple programs, processes, and systems across the Services to be successful. It also involves the creation of a strong Joint culture to move the concept through the implementation milestones. While this does not mean dismantling Service culture altogether, it creates a sense of interconnectedness that moves the Services beyond cross-Service awareness toward cross-Service cooperation.

Implementing a Two-Way Communication Strategy for JADC2

To bridge this gap, "collaboration is the key because digital immigrants are those who invented technologies and systems that digital natives today use fluently."[224] Any communication strategy for JADC2 should flatten communication as much as possible, finding the middle ground between the various spectrum of digital dwellers within the stakeholder community.

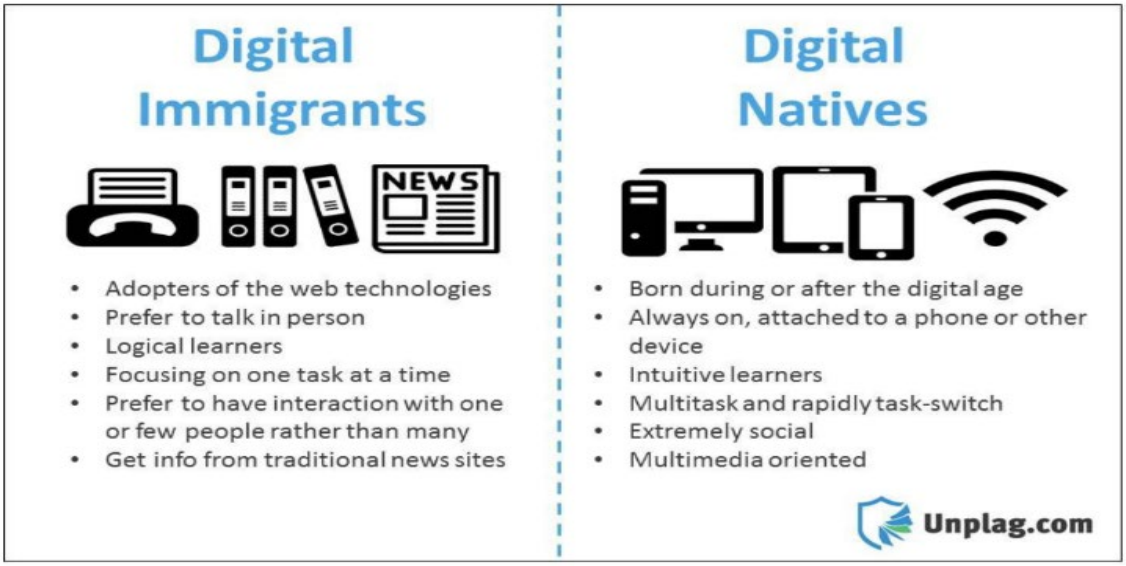


Figure 10: Digital Migrants vs Digital Natives (source: Medium.com) [225]

During the early discourse on the JADC2 framework, the Air Force pointed toward the Uber model to illustrate MDC2. At the 2019 Space and Cyber Conference, Preston Dunlap likened bringing together networks, algorithms, and artificial intelligence for battlefield decision-making to how Uber uses this combination to get "the right person to the right car."[226] The Army used similar language, adding that this web of integration would connect every sensor to every shooter to enable the delivery of battlefield effects. While the concept and language of JADC2 have matured beyond the Uber vignette, the illustration created an image that made a conceptual outcome realistic. Regardless of generation or comfort with digital technology, getting what you need with a swipe on a mobile device created a common understanding that allowed stakeholders to easily see where they fit and could contribute to the evolution of the concept. The language was understandable and set a common ground for multiple stakeholders to facilitate a credible dialogue. The Uber illustration demonstrated the balance between flexibility and concise vision needed to power disciplined creativity. When using Uber to describe the desired outcome, Dunlap chose language that acknowledged that discovery required room to fail forward without critically compromising credibility. As the JADC2 framework becomes more refined, the DoD must be deliberate in injecting a similar level of clarity into communication and engagements with internal and external stakeholders.

Meeting People Where They Are - Finding the Language of the Middle. Tech giant Amazon uses a concept called working backward as their visualization process. This process requires the project leader to draft a press release describing the experience that they want their customer to have. This press release is part of their initial idea pitch and is crafted well before the project is courted to the firm's decision-makers for consideration.[227] By working from the view of the finished experience instead of working towards an idea, Amazon leaders build the language they want their team to coalesce before launching and providing an anchor point to advances concepts to delivered critical outcomes.[228]

The press release and frequently asked questions (FAQ) sheet, which is called *press release/FAQ* on the process chart, also aims to bridge multiple communication divides by placing the customer experience foremost in the minds of the concept developers. Having the project lead as an active participant in shaping the desired perception ties them more closely with the customer. Choosing a language that resonates with their customers helps them to find the language of the middle. Consistently using this language to engage parties both inside and outside of the company helps drive success.

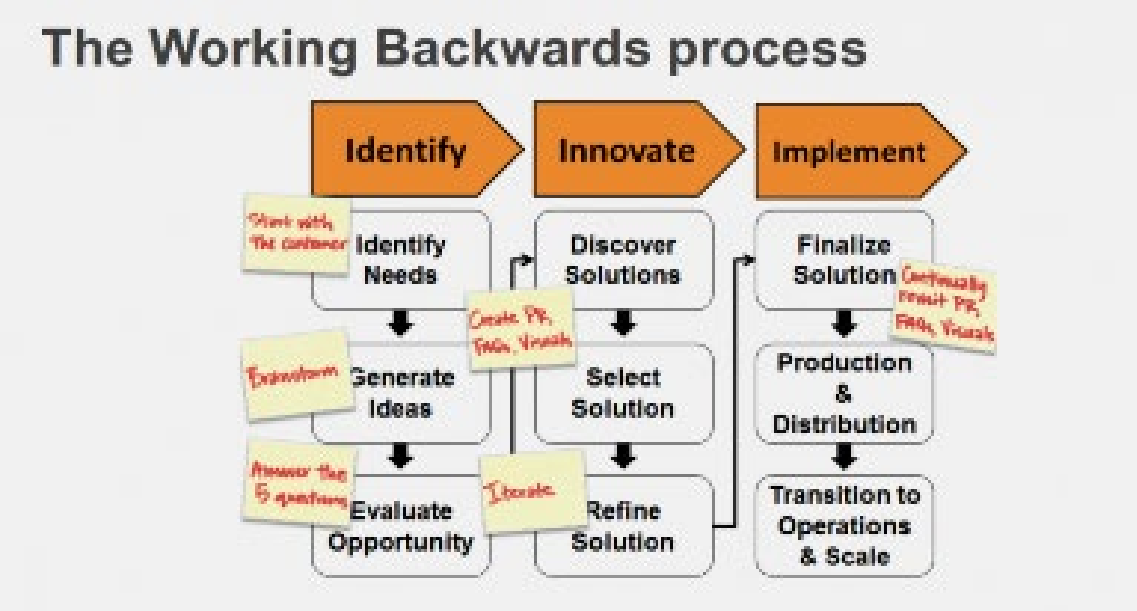


Figure 11: Working Backwards Process (source: Robosoft Technologies)[229]

While the pure application of this concept does not easily translate to the DoD, the theory behind it does. The DoD backward plans operations but forward plans public communication and engagement. The Amazon approach suggests developing communication in tandem with the development of an operational concept. Developing a shared view of the DoD "customer" experience keeps the Department and its stakeholders focused on the solution's utility. Iterating on the narrative of the experience throughout the critical stages of implementation helps refine the language of change while maintaining focus on outcomes. While the implementation of JADC2 requires very technical discussions, working backward suggests that everything should link to an easily digestible vision of how warfighters experience joint integration on the battlefield as opposed to simply paying attention to what powers the experience. Converging on what Amazon calls the press release/FAQ could serve as the foundation for how we shape future discussions on JADC2 both internally and externally.

Engraining Diversity, Equity, and Inclusion into JADC2 Implementation

Diversity and Behaviors. Behavior is a product of both the situation (e.g., cultural influences, social roles, and the presence of bystanders) and of the person (e.g., personality characteristics).[230] How an organization represents its mission portrays its behaviors. Behaviors will influence how the Department of Defense transforms its Services' and interagency performances to execute the JADC2 vision. Interoperable architecture and data are vital to

dominating all domains. It is the future of streamlining command and control capabilities between military Services and the interagency. It is also the linchpin to advancing technology above our adversaries. However, the people and the diversity thereof drive the deliverables. Interoperability is not and should not calibrate to a single Service. It must be co-joined with our allies and entrenched in the intelligence community. The future common operating picture is now. Our adversaries have become aggressive, advancing in technology, and use unconventional tactics to intrude and disrupt across domains. JADC2 requires the right people, in the right place, at the right time, and with the proper authorities. The behaviors of the DoD and the national security apparatus will influence how JADC2 is perceived, executed, and operationalized for mission today and mission tomorrow. They must take lessons learned and omitted from past operations and strategy executions to change the narrative to model inclusive, diverse behaviors and improve the mindset of the Services. JADC2 envisions forging interoperability between concurrently running C2 contributions from the Army, Navy, and Air Force. However, key stakeholders remain visibly absent from the vision. The JADC2 Strategy seems to be promoted in a vacuum.

Diversity is About the Talent Mix. Inclusion is about making the mix work.[231] JADC2 is about the diversity in systems, data, architecture, relationships, and people. Inclusion creates a system where they can all communicate. The success of the program actions each represented stakeholder. A homogenous framework and architecture will only support data pre-existing in a stovepipe. JADC2 offers an opportunity to promote diversity. JADC2 leaders should advocate for solutions that overcome the lack of diversity in the Services and interagency in STEM fields and innovation centers through long-term investments and continuous engagement. The defense industrial base acknowledges the lack of diversity in their organizations. The big five have diversity, inclusion, and equity reports highlighting underrepresentation. For example, at Lockheed Martin (LM), there are 114,000 employees. 28% of LM employees self-identify as a Person of color; 14% of executives self-identify as a person of color; 8% of Board of Directors self-identify as a person of color. Inclusion is about empowerment, engagement, and respect. JADC2 is an emerging market with the opportunity to promote DEI with all stakeholders and internally provide them with demonstrated and visible representation of race, color, and gender.

Appendix H: JADC2 Organization Structure and Policies Assessment

Organizational Structures Supporting the JADC2 Efforts

The DoD recognizes the importance of moving quickly and has published a JADC2 Vision Statement, Strategy, and the JADC2 implementation plan. This aggressive approach is moving the DoD in the right direction. However, the DoD may fail to realize the full potential of JADC2 without a critical review of the current policies and authorities governing command and control and the military acquisition process. The U.S. military does not currently possess either the technological capability or the authorities and policies to take JADC2 from concept to fully operationalized doctrine.[232] The standing policies and authorities act as an obstacle to the Joint Force. The Joint Force lacks the authority to compel the Services toward progress on the actualization of JADC2. With funding for acquisitions and programming retained at the Service level, the Joint Staff lacks the forcing function to direct and manage Service behavior. For JADC2 to work, a comprehensive review of the standing authorities and policies must occur. The U.S. military must take the current JADC2 strategy and cross-reference the ongoing command and control initiatives throughout the Services (Project Convergence, Project Overmatch, and ABMS) and find areas of unity that lead the Joint force to an all-Service solution for command and control. The requirements for JADC2 are not solely a technological solution.

Leadership Versus Coordination of JADC2. Since JADC2 is a joint concept, one may believe that the Joint Staff that controls. However, the roles and responsibilities of the Joint Staff as defined by Title 10 Code are: to ensure the personnel readiness, policy, planning, and training of the Services through their respective Service Chiefs for the combatant commanders to utilize.[233] The Joint Staff does not possess the authority to task Services directly, and it cannot compel the Services through other means, especially funding. Ultimately, the Joint Staff is the organization responsible for the planning, implementation, and execution of JADC2. Traditionally, this role would fall under the Joint Staff J5 directorate as they are responsible for strategic plans and policy, or the J3 directorate responsible for joint operations. However, the JADC2 vision, strategy, and implementation plan identify the concept as falling under the control of the Joint Staff J6.[234]

This definition of control is challenging and lacks clarity. The J6 is traditionally responsible for improving the joint force's interoperability, primarily a directed emphasis on communication systems and architecture.[235] The role as the lead agency is expanding the focus of the J6, and the JADC2 framework goes beyond communication systems and architecture as it spans information flow through all domains and across all classification levels. The J6 CFT addresses how they will oversee the implementation of JADC2. They have aligned the CFTs to the five lines of effort identified in the strategy; Data Enterprise, Human Enterprise, Technical Enterprise, Nuclear Command, Control, and Communications (NC3), and Mission Partner Information Sharing.[236]

Conflicting Roles and Responsibilities. JADC2 as a concept challenges the traditional roles and responsibilities of the commander and raises friction points pertaining to "who controls forces."[237] In conflict, command of forces is the responsibility of the geographic combatant commander. The roles and responsibilities of the combatant commander as per title 10 U.S. Code 164 are "…the performance of missions assigned to that command by the President or by the

Secretary with the approval of the President."[238] Included in this are the production of operational plans, contingency plans, exercises, conducting military operations throughout the commander's designated AOR to ensure deterrence, and if deterrence fails, conduct military operations as assigned by the President.[239] The roles and responsibilities do not cover personnel, training, equipping, and modernization. These responsibilities fall to the military Service chiefs. Per Title 10 U.S. Code, the military Service chiefs are members of the Joint Chiefs of Staff and offer military advice to the President, SecDef, and the National Security Council, and they are responsible to "the Secretaries of their military departments for the management of their Services."[240] These responsibilities include all Service innovation and modernization and current and future acquisitions and legacy programs of record. The answer to "who" controls JADC2 becomes abundantly clear when viewed through this lens. It is the Services that control the future of all domain command and control, not the Joint Staff and especially not the J6.

Ownership of the Processes and Procedures and How Services Retain Control. The Services manage the essential tool for innovation and modernization of any kind. That tool is the budget. The Services create, advocate for, and manage their Service budget, accomplished overtime through the Future Years Defense Program (FYDP). The FYDP, an internal DoD database and accounting system, serves as the primary planning tool for Services to anticipate changes to programs or priorities.[241] The FYDP accounts for systems and support systems within a program of record. The FYDP considers the forecasting for five years, the current budgeted year plus four additional years, and updates during the Planning, Programming, Budgeting, and Execution (PPBE) cycle. The Services create a Program Objective Memorandum (POM) and Budget Estimate Submission (BES) for review and approval by the SECDEF and then inclusion in the President's Budget. Of the twelve Major Force Programs, Program 3 is Command, Control, Communications, Intelligence, and Space.[242] The Services maintain complete control of the planning for funding during this process.

The Joint Staff does maintain some leverage when it comes to new and emergent technology and programs through the JROC. The JROC oversees the development and integration of joint operational requirements through the Joint Capabilities Integration and Development System process (JCIDS). Chaired by the Vice-Chairmen of the Joint Chiefs of Staff, the JROC provide some power of the purse to the Joint Staff through the formal processes. But the Services still set Service priorities and manage the long-term budgeting requirements.[243] The JROC leaves the J6 directorate in an oversight position but lacking fundamental tools to manage and direct Service budgeting priorities.

Even before the establishment of the JADC2 CFT, Services advanced their own programs for multi-domain C2 and for years have conducted concept development, concept evaluation, and, most importantly, changes to their acquisition's behavior. Services identified this problem and created validated requirements through their internal concept development programs. However, the problem remains that their requirements are not inherently joint. The Air Force ABMS, the Navy's Project Overmatch, and the Army's Project Convergence are driving the future of JADC2.[244] These concepts leave the J6 in the position of digital integrator, providing at best bridging solutions to emergent technologies and vice the driving force behind JADC2.

The problem does not stop at the Services. The Joint Staff lacks influence over the major defense industries due to long-term programs that fulfil Service requirements. Very few programs exist as fully joint PoR, and the one that does exist today, the F-35 Joint Strike Fighter,

is not the use case to study as an example of why more Joint programs are needed. It is quite the opposite. Viewed as monolithic, slow to need, and unsuccessful at meeting Service-specific requirements, Joint programs fail more than succeed. The J6 can still provide oversight through the JROC process with the CFTs; therefore, this is still a form of control. There are potential flaws embedded throughout that approach. Service culture, bureaucracy, and competition for funding and missions create an environment that results in duplicative efforts. Often, domain-specific systems are not interoperable across Services, allies, and partners with significant outlays. This approach leaves the CCMD in the position of having to piece together Service-specific systems and platforms to create a joint solution.[245] The J6 can still maintain control of JADC2 but not through oversight alone. A more creative approach to maneuvering through the existing processes and creating a headquarters to manage data governance can enable the J6 to ensure that "jointness" is not an afterthought but a priority in Service's current concept development programs.

Progress Towards a Joint Solution to JADC2. Complete defense acquisition reform is considered the only way to fix the procurement processes of the DoD. However, a task of this magnitude is all-consuming and would detract from the time now requirements as our adversaries continue to drive the global tempo of great power competition. Disregard complete defense acquisition reform, find ways to maneuver within it and get the system to work for the J6. Control of data and data fabrics and the APIs used as the digital integrator will enable control for the J6. Small, subtle changes to the Service's approach toward acquisitions and programming driven by the Joint Staff and managed through the JADC2 CFTs can significantly influence future command and control systems. The CFTs, as advisors to the JROC, can advise on more mission-based requirements centered around software-defined systems that utilize an open data architecture vice platform-based requirements.[246] This fundamental change in programming for mission requirements creates an environment where software-defined systems are platform agnostic. Software becomes the critical component of programming for future systems. The CFTs can drive the need for access to legacy systems software. This access will ensure that the weapons systems used in the future fight have the interoperability required to seamlessly communicate and transmit data, meeting legacy systems where they are and allowing them into the new architecture. The DIB is critical to gaining access to legacy systems software, and open architecture is key. The DIB has demonstrated extreme willingness to grant access to DoD programs; this is an area where the JADC2 CFT can seize control.[247]

The JADC2 CFT can identify ways to bifurcate the systems approach by seeking out and identifying a series of ecosystems vice one joint mega system. A monolithic, robust, singular joint program for command and control is not tactically savvy. It will be mired in bureaucratic maneuvering, more than likely dying while making its way through the process. More miniature well-connected ecosystems with clear pathways to data sharing through open architecture and sharded data fabrics can fully enable JADC2 without completely reforming the framework of the current acquisition processes.[248] Authorities become key when discussing open architecture and shared data fabrics. Digital backbones must have governance and an agreed-upon risk management framework. The DoD has a Chief Information Officer and Chief Digital and Artificial Intelligence Officer, but these positions lack formal military command and control authorities.[249] Suppose the DoD desires to create government-owned APIs to connect disparate forms of data to form the foundation of JADC2. In that case, the DoD will need to establish and enforce published data standards, fund the connections for the data ecosystems to the warfighter,

and validate the efficacy of the systems through joint exercises.[250] It is possible for them to do so through OSD directives and policies. However, there lacks an enforcement and oversight body. In order to achieve this level of connectedness, some have offered that the DoD could establish a joint headquarters to manage and, when necessary, direct the Services through this digital governance. There are merits to this recommendation that deserve some consideration. A revitalized and reimaged Joint Forces Command (JFCOM) that has the roles and responsibility as the authoritative headquarters for the digital enterprise for the Joint Force can fulfill this requirement with a small agile staff of military and civilian employees.[251]

Agreed upon and published data standards enforced by JFCOM will enable the Joint Force to capitalize on the most critical aspect of the future of warfare, data. As the Chief of Naval Research, Rear Admiral Lorin Selby, said, "data is the new oil [and] software is the new steel."[252] Admiral Selby is correct in his analogy. With this widely accepted understanding of the critical importance of data, a Joint Command can exploit the benefits already achieved by the Services through their mature concept development in command and control. JFCOM will not hinder the forward progress of the Servicers. JFCOM will ensure adherence to published data standards and seamless data flow from Service-specific data fabrics connected across domains through cross-cutting joint APIs. JFCOM will develop and fund the cross-domain API solutions. JFCOM, through a risk management framework, will transition from a compliance-based risk framework to one that enables the Services to manage the risk at the tactical level according to published data standards.[253] This framework currently exists in a nascent form with the Modular Systems Approach outlined in the National Defense Authorization Act.[254] An established and agreed-upon approach will significantly enhance the Joint Force in its progress towards JADC2 and set conditions for the entrance of Mission Partner Elements (Allies and Partners).

JADC2 is not just a requirement but a necessity if the Joint Force wants to achieve its objectives in a future conflict. JADC2 is changing how the Joint Force senses, makes sense, and disseminates information focusing on implementing command and control. When viewed together with the Joint War Fighting Concept, the changing character of war begins to emerge. As Carl Van Clausewitz stated in On War, "The nature of war will remain the same, but the character will change."[255] This statement still holds today. As the DoD looks to modernize how it fights future wars, it needs to ensure that standing policies and authorities evolve. JADC2 will fail to meet its true potential if the current policies and authorities remain unchanged. Small changes in who controls JADC2 and how it's implemented will significantly influence its future success.

Standardization Requirements for System Interoperability. The ability for systems across all domains and Services to collect and transmit actionable data quickly and efficiently is imperative to the C4ISR community, and it moves closer to JADC2. Data interoperability is the missing link to connecting sensor to shooter in the Joint environment. Data interoperability is the ability of systems, units, or forces to access, share, and use data from other systems, units, or forces to operate effectively on the battlefield.[256] As the U.S. defense increases its reliance on space and unmanned aerial systems, the more challenging and complicated data interoperability will be between all domains and platforms as a result of proprietary systems, concerns surrounding intellectual property, and data proliferation, all of which will have an impact on advancing JADC2.

Proprietary systems create a significant problem with interoperability. The core of systems architecture determines if a system can link to other systems to access, share and use data, hence the problem with proprietary systems. Concerns about proprietary systems are not new. In 2014, the Assistant Secretary of Defense for Acquisition, speaking at the Defense Daily Open Architecture Summit, emphasized that "taking proprietary, closed systems and adding open interfaces to them is currently DoD's biggest challenge on the open architecture front."[257] Proprietary systems not only create a problem with data interoperability, but they also hinder the advancement of new technologies such as AI programs as the lack of access to software and data storage of commercial vendors prevent the distribution of data across systems.[258] More recently, the DoD/CIO posits that an agency that fails to consider open-source software and only builds proprietary software and systems excludes a significant part of the commercial market and hinders future modifications.[259] In a data-driven environment, the DoD must be conscious of proprietary systems design and start addressing the issues with intellectual property (IP) that prevent the defense industrial base from designing more open systems to enable data interoperability.

A significant data interoperability challenge is the threat of losing IP. Defense contractors, agencies, and other stakeholders fear inappropriate disclosure of intellectual property if they share confidential and proprietary data or produce open systems. Protecting IP has been problematic in the Defense Department for many years, and the problems are growing as innovation within the private industry is increasing at an extreme rate. Determining the right balance between what IP to keep and what IP to let businesses retain to protect their investment has been a struggle for DoD for several years. Congress has tried to manage this issue for many years. After decades of reporting on IP issues, the Government Accountability Office (GAO) claims that insufficient IP can reduce mission readiness and lead to surging costs.[260] The DoD purchases and licenses IP for systems and software associated with BMC2 and technical data for exquisite weapon systems. In many cases, the Department does not own the IP it needs to operate and maintain those systems and make future modifications to ensure interoperability with new platforms. As a result, data becomes unshareable, and the price of modifying old systems soars, forcing the DoD to buy new systems or pay the hefty cost of changing the existing ones. The concern over IP creates a tremendous problem, and policymakers must work hard to ensure IP does not continue to hinder data interoperability as the DoD moves forward with JADC2.

The final challenge to data interoperability is data proliferation. Opening networks up to too much data and information causes problems. Consider Russia's cyberattack against Ukraine in 2014 as it moved to take control of Crimea. Russia simply flooded Ukrainian networks with data, causing a distributed denial-of-service attack that crushed Ukraine's communication ability. Pushing more data to the digital systems than the systems could process created a digital traffic jam preventing good mission-related communications from getting through, creating chaos for the Ukrainian military. The same applies to too much data being pushed or even available to leaders and shooters on the battlefield. A cyberattack is not causing data overload for the military. The problem is self-inflicted. Instead, the U.S. military is creating its own data burden by generating more data than it can process, resulting in an inability to execute missions. In 2014, a Rand study projected the DoD's digital footprint would increase exponentially to over 40 billion terabytes by 2020, from below 500 million terabytes in 2005 due to a rise in and

improvement of sensor quality and quantity.[261] While sensor quality and quantity continue to rise, the ability to manage and process the growing amount of data is falling behind, creating an input-output problem known to computer programmers as garbage in, garbage out. Essentially, the massive influx of data may overwhelm the warfighters increasing the fog and friction and causing errors and indecisiveness. This data interoperability challenge highlights the inverse of not being able to access and share data. The DoD's inability to sift through data that is not important and push forward relevant data to the warfighter is a data interoperability challenge because it crowds the battlespace slowing down decisions at a given time. Indeed, DoD must address the data proliferation challenge to ensure the right data is transmitted to the right shooter at the right time for JADC2 to be successful.

Standardization Requirements for Development Environment.

A common DevSecOps software platform enables disaggregated C2 and enables resiliency, security, cost efficiencies, and wide industry and academia participation in a JADC2 innovation ecosystem. However, the common platform requires trade-offs is counter to traditional, service and program of record (PoR) software development.

JADC2 and Disaggregated C2. Disaggregated C2 is a key characteristic of JADC2. Traditional C2 structures are centralized into weapon systems like the Air Operations Center (AOC), Command Reporting Center (CRC), Airborne Warning and Control System (AWACs), and Joint Surveillance Target Attack Radar System (JSTARS).[262] These approaches tightly *couple* functions, data required, and data produced to the individual weapon systems. If those weapon systems are destroyed or malfunction, the functions they perform cannot be replicated and capability is lost. For example, an Air Tasking Order (ATO) can only be produced within the brick-and-mortar theater AOC. The U.S. Air Force recognizes the AOC is therefore a large target and vulnerability.[263] In contrast, the future operating environment presumes a highly contested environment where the functions and data required to execute C2 must be loosely coupled, or disaggregated, to improve resiliency and preserve capability. Air Force officials noted, "I need to be able to C2 multiple things from different places all in real-time and all talking to each other so that we're going to be integrated rather than synchronized."[264] Whereas today only the brick-and-mortar AOC can produce an ATO, the envisioned future demands that ATO could be produced from AOC, aircraft, ships, or mobile vehicles.[265] For example, if the theater AOC was destroyed, its functionality could be replicated by one-to-many systems with access to the data required to perform the functions. Such a disaggregated C2 future requires software, hereafter referred to as "C2 Applications," able to operate on multiple weapon systems. However, legacy C2 systems are developed without such application portability. That model must change and a common DevSecOps platform is an enabling technology. The DoD JADC2 Reference Architecture in fact identifies DevSecOps as a core JADC2 enabler.[266] The JADC2 CFT is focused on establishing a common platform for continuous software development and delivery.[267]

Defining DevSecOps and a DevSecOps Platform. DevSecOps is, "… an organizational software engineering culture and practice that aims at unifying software development (Dev), security (Sec) and operations (Ops)" and focuses on building and testing functional and security capabilities simultaneously throughout software life cycle.[268] Its advantages include increased development time, deployment frequency, automated risk monitoring and mitigation, and security.[269] From a JADC2 perspective, DevSecOps provides the ability to rapidly develop,

deploy, and update operational software-based capability. One technological enabler of the DevSecOps culture and practice is the platform. The platform is the "group of resources and capabilities that form a base upon which other capabilities or services are built and operated."[270] A key nuance is that the platform provides the resources to build *and operate* the software; it is not simply a software development environment. The platform provides a standard configuration of software tools and services that enables the software development, test, operation, and management without having to provide common infrastructure and services. For example, the platform includes things like the operating system (e.g., Windows), development management (e.g., JIRA), test tools, and security controls. These platform capabilities would otherwise require time and money to substantiate for each software application. Instead, the platform is standardized and provided for the "mission" specific software built "on top of it". A common platform can run any applications developed on it. By comparison, legacy software was often built within virtual machines that grouped the operating systems, libraires, and tools into virtual machines for each unique mission.[271]

JADC2 Advantages using a common DevSecOps Platform. JADC2 will require rapid C2 application portability. It demands rapid decision making enabled by data and algorithms whether from within traditional brick-and-mortar facilities or individual warfighters in the air, land, or sea. A commercial user today can run Google Maps from their "devices" (e.g., laptop, tablet, smartphone, or vehicle). The warfighter tomorrow requires similar flexibility with data and applications required to execute warfare. A common DevSecOps platform maximizes application portability and minimizes time and cost required to integrate new applications across their "devices". The flexibility commercial users today with their smartphones are enabled by the smartphone providing the underlying tools and capabilities; the application provider need only concentrate on their software. A common platform also improves C2 Application portability across multiple security levels, which is a critical need within JADC2.[272] C2 Applications must run at multiple security levels, regardless of the security level in which they were developed. A common platform provides a consistent set of tools that ensures application portability across networks.

Common Security Architecture. A platform provides the underlying security tools that establish access and authentication for users, devices, and services.[273] The common tools ensure more stringent security enforcement and consistent user experience. The approach also best enables achieving continuous Authority to Operate within DoD networks, which is often a challenge to achieve and maintain. Another JADC2 enabling technology is Zero Trust. The Zero Trust discussion is outside this paper's scope, but the common platform and its associated tools are foundational elements to implementing Zero Trust within the software realm.[274]

Common Security Monitoring. Related to the common security architecture is security monitoring. The common platform enables consistent cyber-security monitoring whether in application development, test, or operations. The more platforms there are, the more unique security monitoring requirements that drive cost and complexity.[275]

Cost Efficiency. Platforms are expensive. Exactly how expensive is unclear, but two data points indicate tens of millions of dollars per year. First, open press reporting on the U.S. Air Force's PlatformONE indicates a staff of 275 personnel with 90% contractors.[276] A Government Service Agency labor rates of $150 an hour equates to over $70 million per year. The U.S. Air Force's Kessel Run organization uses the All-Domain Common Platform (ADCP) for its Air

Operations Center software. According to Air Force budget documents, it requested $64 million in FY21 for ADCP. Additionally, the Army Software Factory is leveraging a separate platform called CReATE at unknown cost.[277] The Navy has initiated a pathfinder called Black Pearl with unknown costs.[278] Traditional acquisition approaches would pass these costs onto the programs of record, which would rely upon the contractor to provide the platform (and also put the aforementioned benefits at risk). Leverage commercial investment and technology. The DevSecOps market is expected to be over $41 billion by 2030 with a 30% compounded annual growth rate.[279] The demand for platforms will increase and presumably the number of suppliers will as well. The large commercial demand provides DoD an opportunity to leverage commercial technology and avoid traditional oligopolies amongst large defense contractors. For example, the tools within PlatformONE are commercial.[280]

Expanded JADC2 Ecosystem. A common platform, distributed amongst potential JADC2 contributors within academia, laboratories, Services, and industry lowers barriers to entry, ensures solutions are more easily transferable between developers, weapon systems, and warfighters. It enables Rapid-Iterative-Collaborative-Experimentation (RICE) where JADC2 solutions could be quickly prototyped without formal contract mechanisms or agreements that tend to introduce time delays.[281]

Challenges using a common DevSecOps Platform. An enterprise platform requires dedicated funding and personnel. As stated, each Service is pursuing their own platforms. The Air Force has identified PlatformONE as its enterprise solution and delivered it across numerous organizations as shown in the picture below available on its website.

Service and Program Stovepipes. The DoD programs, plans, budgets, and executes (PPBE) acquisition efforts through PoR that are predominantly executed within the military Services. Consequently, DoD and Service organizational structures, processes, personnel, and training reflect PPBE and PoR influences. In general, each PoR has a Program Manager responsible for the program cost, schedule, and performance.[282] Their authorities, responsibilities, and influence are constrained to their individual program and not enterprise investments.

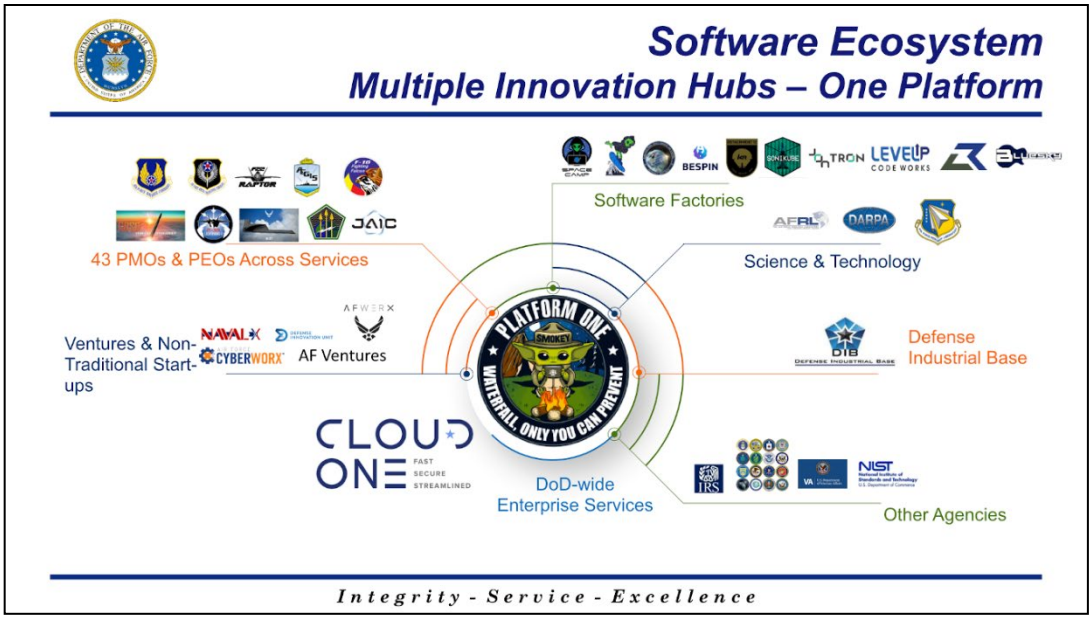


Figure 12: PlatformONE users and ecosystem from the PlatformONE website

The existing JADC2 governance, directed by the DSD and with input into the DoD's highest levels of decision-making processes, provide a venue with department-wide audiences to persuade and generate buy-in for a platform vision, strategy, and implementation.

Legacy C2 Applications. Legacy software was often built within virtual machines that grouped the operating systems, libraires, and tools into virtual machines for each unique mission.[283] The existing infrastructure required to run the platform and software is often on-premises and proprietary. Legacy software can be containerized for compatibility with a common platform, but such endeavors are costly and time intensive. For example, one legacy C2 software program required over $30 million and 12 months to convert legacy code to Kubernetes containers.[284] Legacy C2 applications must therefore be prioritized for conversion, based on the operational value measured by JADC2 CFT mission threads, and funding advocated for based on the results.

Introducing Dependencies into Programs of Record. A Program Manager is disincentivized to add external dependencies to their program. Leveraging an enterprise platform is exactly that. A program's fate would be tied to an enterprise platform performing reliably and as expected. However, the absence of a common platform reduces the critical C2 Application portability that is foundational for disaggregated C2 and JADC2. Having two different programs develop two different C2 applications, on two different vendor proprietary platforms, that cannot work together is no longer an option. An acquisition approach to mitigate dependencies (and preserve the benefits of a common platform) is to establish an enterprise platform and allow individual programs to run their own platforms *compliant with* the enterprise platform. Compliance between platforms is outside the scope of this paper, but such an approach would allow individual program's control over their cost, schedule, and performance while ensuring the C2 Applications developed were compatible with the enterprise and therefore supported disaggregated C2 operations. The Air Force's PlatformONE includes such an option, dubbed it's "Big Bang" service that transfers execution responsibility to the program office. Other Service platform approaches appear significantly less mature.

ANNEX A: C4ISR Market Response to the Russia-Ukraine War

The International Response to the Russia's War on Ukraine.

The U.S. support to NATO and Ukraine ahead of Russia's attack is an example of attempting to attain an information advantage against Russian misinformation and disinformation operations in the information domain.[285] In the past, after the fact release of intelligence and sharing with mission partners provides the adversary the initiative or "first mover" advantage in the information domain. Efforts to dominate the information environment will impact our allies and partners. Before 2022, it would be unthinkable to release intelligence gathered about Russian war plans to forestall war, but the U.S. did.[286] Through integrated coordination across the NATO Alliance and European Union (EU), the U.S. and partners pre-empted Russian disinformation and false flag operations to create greater accountability by directly attributing responsibility for the conflict.[287] The U.S. or partner nations acquire vital information regarding a threat or action of an adversary, but the sharing of that information requires hefty bureaucratic, technical, and security hurdles. Many NATO partners already recognize and support efforts to respond to the malign influencers in the information environment, including nation-states, extremist organizations, and individuals.[288] France even recently established a new national organization responsible for leading this effort.[289]

C4ISR Industry Response to Demand Signals from the Ukraine-Russia War

Ukraine's war is accelerating political buy-in for information sharing and defense spending against a common threat, not just for Europe but also for global threats including North Korea, Iran, and violent extremists. The U.S., partners, and allied nations' leaders recognize the greater significance and demands to develop new concepts and modernize for the new era of GPC.

Requirements for C4ISR Platforms and Related C2 Systems. Although much of the capabilities and systems provided to Ukraine remain classified and close-hold, DIB firms confirmed that they are supporting aid and assistance efforts to the U.S., Ukraine, and NATO forces. Firms expressed their responsiveness to increased production requirements. In a way, the recent conflict is a partial mobilization of the C4ISR capabilities to partners and allies to enable their sense-make sense-act capabilities on the battlefield.

Among these capabilities are C2 systems, aerial and ground intelligence collection systems, and communications systems. These key capabilities enable cross-Service and multinational operations and operational support. The DoD has facilitated the procurement of commercial platforms to support Ukrainian forces in addition to military-grade hardware and weapons systems.

Examples of Enduring Requirements Beyond the Conflict. The Ukraine crisis will require NATO and U.S. forces to maintain increased intelligence and warning systems in place to enable early warning and provide increased options. These systems and platforms will be multinational and require integration. The JADC2 efforts ongoing in labs and fielded for testing and evaluations will need to rapidly transition into enduring solutions. Standardization across the Joint Force will enable cross-Service and multinational operations and readiness.

Recommended JADC2 Industry Policies to Support DoD Response

Advance Multinational Mission Partner Integration (Process, Systems, and Networks through Standardization and Investment)

The global war on terror increased knowledge and awareness of the inability to share relevant and timely information with partners to allow them to act. Exchanging information between coalition partners, different CCMDs, and other federal agencies was time-consuming and manual. Government personnel had to pick up the phone to figure out what was happening on the ground, relay between several Combatant and Support Commands, and share relevant information with a federal agency via Google Docs.[290] The complications of sharing information during military operations are not new for the U.S. The Invasion of Grenada in 1983 highlighted the non-compatibility of the different Services in the U.S. military, directly contributing to the subsequent Goldwater-Nichols Act to improve communication, coordination, and unify joint forces under one command.[291] Similarly, the U.S. withdrawal from Afghanistan also underscored the lack of a common operating picture (COP) and lack of communication with allies and partners on the ground.

Afghanistan Mission Network (AMN) and NATO's Federated Mission Networking. After spending nearly a decade on the ground in Afghanistan, the Afghanistan Mission Network (AMN) became the primary C5ISR network for NATO-led missions in Afghanistan, AMN was a revolutionary shift in thinking from "need-to-know" to "need-to-share," enabling better coordination and communication between all coalition participants (ISAF). The AMN core federated connections with U.S.' CENTRIX-ISAF, GBR's OVERTASK, CAN's LCSS, ITA's CAESARNet, etc. First established in Jan 2010, AMN had 48 different partner nations operating on the federated network system by 2011.[292] Because of successes and lessons learned from AMN, NATO also adopted a federated network to enable information sharing within NATO and with other non-NATO entities participating in a coalition environment. The Federated Mission Networking (FMN) is documented in FMN Spiral Specifications, which essentially lay out how different nations wanting to connect to each other for coalition missions could connect. FMN takes the original AMN concept and improves upon it, making the NATO FMN simpler, more robust, faster setup, easier management, easier sharing of information, more flexible, and more cost-effective.[293] So far, 35 nations have joined the FMN initiative, working together to develop, connect, and conduct net-centric operations.

Mission Partner Challenges. Some limiters of JADC2 mission partner efforts include law, treaties, and bilaterals; authorities; and relationships, For example, many countries may have no issues sharing information with the U.S. However, France and Germany may have issues sharing information with each other, Similarly, South Korea and Japan may have issues sharing information with each other. Thus, the idea that all allies and partner nations are on the same network, and could potentially share information with each other, raises concerns and political considerations. When talking with industry, research partners, Services, and agencies, there was push-back on the feasibility of information sharing with mission partners.[294] One industry partner could not foresee a situation where mission partners would be on the same network as the U.S., even for our closest allies, Great Britain, Canada, Australia, and New Zealand. Their plans for JADC2 did not even consider this possibility. Perhaps tellingly, Booz Allen Hamilton's Greg Wenzel disregarded AMN efforts to network Services and mission

partners together when asked about taking AMN and evolving it to enable JADC2 efforts, Instead, he called for "a different type of networking than what we did during the last two decades" to connect Services and did not mention allies and partners at all.[295] One agency partner pointed out that policy and authorities would prohibit information sharing, just as it does today. Even current efforts to pass along valuable information to recent actions on the ground in Ukraine requires special, non-delegable authorization from one of the highest leaders in the U.S. Intelligence Community.[296] Last year's C4ISR seminar (ES AY21) pointed out that partners and allies are a great strength for the U.S. Still, partners and allies are usually considered after the fact leading to integration issues.[297] In short, there need to be policy changes, culture and mindset changes, willingness, and trust to integrate our allies and partners truly.

Mission Partner Progress. JADC2 subject matter experts acknowledge that a change in policies, from security to classification, to increase capacity for mission partner networking is needed.[298] They point to the continued support and backing of the Vice Chairman of the Joint Chiefs of Staff and the Deputy Secretary of Defense, especially as they examine which policies or authorities need to be changed or even added. They also point to common standards, certificates, and specifications that NATO members use today, which could easily support other JADC2 efforts. A central technical idea being pushed is a new network to connect and operate with allies and partners (Secret and Below Releasable Environment, or SABRE).[299] This network would hold restricted information separate from releasable information based upon the classification metadata of the information. NATO's FMN is considered the fruit of ten years of work to figure out mission partners. SABRE would take FMN further by providing a single tactical network for countries, potentially subsuming the separate NIPR and SIPR networks. This new network would allow for the integration of coalition and interagency data from the start, emphasizing data-centricity. Exclusive data ownership would change towards responsible distributed data management. And there would be a push to change mindsets from "need to know" to "need to share" to increase information and intelligence sharing. However, because of multiple allies and partners sharing information, whether for missions or operations, the inclusion of DoD in international agreements between countries and the U.S. State Department would be needed. These agreements would set the stage for ally and partner information sharing. The U.S. has had successes in the mission partner environment.[300] NATO's FMN had at least 22 nations participating in CWIX 2020.[301] There are already 35 FMN affiliates with more countries interested in joining, such as South Korea.[302] Additionally, NATO partners are currently using FMN to communicate regarding the ongoing Russo-Ukrainian War.[303] Per conversation with mission partners, "Mission Partner Environment (MPE) is the U.S.' contribution to NATO's FMN," with INDOPACOM launching their SABRE effort this summer, followed by Europe's shortly afterward (timeline unspecified).[304]

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