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Status quo joint air-ground command and control systems featured in doctrine publications are insufficient to counter Anti-Access/Area-Denial (A2/AD), which requires evaluation through the rubric of a refined Joint All Domain Operations (JADO) theory. DoD and congressional investments into JADO technologies reveal that joint, frame-worked prioritization is the answer to defeating A2/AD. Air Force JADO, Marine Expeditionary Advanced Base Operations (EABO), and Army Multi-Domain Operations (MDO) concepts will counter A2/AD because there is an expectation of jointness delivering coherent battlefield framework and optimal prioritization. The Joint Force requires a comprehensive, top-down, JADO theory that weaves across these emerging concepts, informing optimal JADO operational art and design. Once armed with comprehensive operational art and design, the Tactical Air Control Party Weapon System will understand opportunity costs for employment and assess the consequences outside of their immediate purview while operating as a fail-forward C2 node charged with autonomous battle management of convergent all-domain effects.

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Executive Summary

Title: Staying Alive: Air Power in Support of Ground Operations in the Contested Environments of 2035 and Beyond

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Thesis: Status quo joint air-ground command and control systems featured in doctrine publications are insufficient to counter Anti-Access/Area-Denial (A2/AD), which requires evaluation through the rubric of a refined Joint All Domain Operations (JADO) theory. DoD and congressional investments into JADO technologies reveal that joint, frame-worked prioritization is the answer to defeating A2/AD. Air Force JADO, Marine Expeditionary Advanced Base Operations (EABO), and Army Multi-Domain Operations (MDO) concepts will counter A2/AD because there is an expectation of jointness delivering coherent battlefield framework and optimal prioritization. The Joint Force requires a comprehensive, top-down, JADO theory that weaves across these emerging concepts, informing optimal JADO operational art and design. Once armed with comprehensive operational art and design, the Tactical Air Control Party Weapon System will understand opportunity costs for employment and assess the consequences outside of their immediate purview while operating as a fail-forward C2 node charged with autonomous battle management of convergent all-domain effects.

Discussion: Across the military diaspora, non-partisan think tanks, and members of the Armed Services Committee, there is a growing fear of the erosion of America's military superiority and that "the U.S. military could suffer unacceptably high casualties and loss of major capital assets in its next conflict."[1] In response to a growing power parity in adversary's A2/AD capabilities, each service has derived its version of JADO implementation in the next 8-15 years: (1) The Air Force has Multi-Domain Operations Centers, (2) The Army has Multi-Domain Task Forces, (3) the Marine Corps has Expeditionary Advance Base Operations.[2] JADO literature analysis reveals various new concepts that blur or break existing warfighting paradigms, eroding the status quo operational art in joint warfighting without prescribing mitigation measures. Designated component battlespace owners adjudicated asset brokering, airspace management, effects employment, and battle-tracking in the past. Now, JADO envisions low-signature, dispersed forward formations with delegated decision-making authority below the component level to select and apply force packages from all-domain platforms via machine-enabled control systems. Each JADO context will be resource-intensive, requiring careful adjudication of high-value, low-density capabilities or risk-worthy autonomous swarms and drone wingmen, and featuring agile C2 solutions and flexible command relationships. Authorities will need to continuously visualize effects in the land, air, maritime, cyber, and space domains, considering each as mutually important warfighting functions vice denigrating forces into supporting categories or otherwise isolating them within component boundaries. This complexity may result in an operational design featuring "large pools of all-domain capabilities aligned to some mission, function, or area, in which a single commander is both steward and user."[3] These concepts have yet to be combined into a coherent, unified framework by the Joint Force. Available entries to the body of JADO literature are solely concepts for technological linkages, not an all-encompassing operational design for countering enemy A2/AD. Within the context of renewed

Great Power Competition, the DoD is ripe for creating a comprehensive JADO operational design and art strategy, co-authored by civilians immune to service tribalism and advocacy. This effort will ensure that the ensuing doctrinal upheaval and blurring of operational art and tactics is a necessary and well-founded cause in the pursuit of JADO implementation.

Conclusion: Successful JADO will present multiple dilemmas inside the adversary's decision cycle. This success hinges on joint frame-worked prioritization and less confusing terminology that obscures progression across the joint force. Informed by comprehensive JADO theory and operational art/design, the TACP WS can augment, re-organize, and retrain to support all-domain operations regardless of its supported commander's service. In turn, the TACP WS will execute joint all-domain effects convergence as a fail-forward C2 node on behalf of the joint force. The convergence of joint all-domain effects originating from all levels of operations and authorities in time and space allows the TACP WS to feed joint realities that will win the next War by allowing air power to remain the dominant arm of any fight now and in the future.

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THE OPINIONS AND CONCLUSIONS EXPRESSED HEREIN ARE THOSE OF THE INDIVIDUAL STUDENT AUTHOR AND DO NOT NECESSARILY REPRESENT THE VIEWS OF EITHER THE MARINE CORPS COMMAND AND STAFF COLLEGE OR ANY OTHER GOVERNMENTAL AGENCY. REFERENCES TO THIS STUDY SHOULD INCLUDE THE FOREGOING STATEMENT.

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Introduction

Prevailing grand narratives about global affairs' character profoundly influences how Washington postures the Department of Defense (DoD) for conflict or competition with its military rivals. Post-World War II, Washington adopted a containment narrative to counter Russia's communist influence, which generated four decades of corresponding military strategy. Then came the Global War on Terror (GWOT) narrative immediately following the World Trade Center terror attack on September 11, 2001.[4] These narratives shaped the DoD's prevailing theories of victory at the time. For Russian containment, the DoD developed Active Defense Doctrine, which AirLand Battle superseded.[5] For GWOT, the Army led the joint force with the Counterinsurgency Field Manual development, conceptualized by highly-educated military leaders such as General David Petraeus and Lieutenant Colonel John Nagl.[6] Washington is currently promoting a new grand narrative, Great Power Competition (GPC), which "has become the animating construct guiding U.S. foreign policy, certainly the thinking and increasingly the execution," according to Rand Corporation employee Ali Wyne.[7] GPC started with the Bush administration referenced in 141 news articles and expanded under President Obama with 1,021 appearances.[8] It exploded under President Trump with 6,500 public articles and its primacy as the centerpiece to the National Security Strategy and National Defense Strategy narrative.[9]

With the Great Power Competition (GPC) narrative in vogue, the DoD has an implied task to translate the implications of GPC into preparation for future competition and conflict with rival military powers in yet another theory of victory. China and Russia, and to a lesser extent, Iran and North Korea, are named as the key competitors who "have become skilled at operating below the threshold of military conflict-challenging the United States, our allies, and our partners with hostile actions cloaked in deniability."[10] Below the threshold of War, Russia invaded

Georgia and annexed Crimea, likely in response to NATO membership expansion and Vladimir Putin's revisionist ideals. Likewise, China laid claim to disputed island chains in the South China Sea (SCS) and built regional influence through state infrastructure development under its Belt and Road Initiative.

These competition efforts also seek to create a physical geographic buffer zone to blunt the United States and its allies' abilities to generate combat power close to the Russian or Chinese mainland. These buffer zones have been equipped with long-range, high-tech defensive capabilities specifically designed to defeat exquisite, expensive U.S. military weapons platforms like carrier ships, air mobility assets, and even fighter/bomber planes. These layered defenses have their own term as a subset of GPC called Anti-Access/Area-Denial (A2/AD) weapons. According to the Center for Strategic and International Studies, A2/AD is the merging of "political and economic exclusion" and "sophisticated longer-range adversary capabilities and methods like ballistic missiles, submarines, weapons of mass destruction, and offensive space and cyberspace assets" to provide "blanket denial of basing, staging, transit, or over-flight rights."[11]

This paper investigates the DoD's conceptual counter to A2/AD, Joint All Domain Operations (JADO), or "actions by the joint force in all domains that are integrated in planning and synchronized in execution, at speed and scale needed to gain advantage and accomplish the mission."[12] JADO comes into play when circumstances push the United States beyond tolerance or when high-level geopolitical competitions fail. In this case, adversary hostilities cloaked in deniability or salami-slicing infringements on international sovereignty warrant physical intervention, forcing the United States to react with military power. Specifically, this paper focuses on the USAF's future role within JADO. The USAF will retain its ability to Command

and Control (C2) joint all domain effects in a denied environment through a fail-forward C2 organization with the requisite skillsets to adapt as emerging JADO operators. To orient on where the Air Force envisions its future end state in JADO, one must understand why the status quo needs to change.

Chinese and Russian Anti-Access/Area Denial (A2/AD) capabilities generate a litany of complications impacting the Air Force's current Theater Air Control System (TACS) capability.[13] The threats penetrate to the lowest echelon, the Tactical Air Control Party (TACP), and the Joint partners it supports. Military analysts estimate that status quo communication methods and network architecture are vulnerable now and in the future. The U.S. military can expect its global communications infrastructure to face degradation, denial of service, or destruction; transatlantic fiber optics cables severed, Satellite Communications (SATCOM) degraded or kinetically destroyed, Line-of-Sight Communications in VHF/UHF jammed.[14] The emerging long-range kinetic threats nested within adversary buffer zones, coupled with communications-denial technologies and the abundance of friendly or enemy information, all converge to negatively impact the Air Force's future ability to C2 its air, space, and cyber forces.[15]

In response, the Air Force intends to decentralize its functions held by the TACS across distributed Multi-Domain Operations Centers (MDOC), employing JADO enabled by a new technological 'internet of things' approach labeled Advanced Battle Management System (ABMS).[16] This operational effort will sustain the Air Force's ability to control its domains from the operational through the tactical level of military operations by complicating and overwhelming adversary A2/AD with multiple dilemmas. Air Force C2 functions' emerging decentralized nature means tactical scenarios will require operational or even national level

adjudications for weapons pairing and apportionment. Authorities typically held at the operational or higher levels will need to be delegated to the tactical level in some circumstances, requiring operational art to reference simultaneous action delivered by the formation at the front end of this new construct, the Tactical Air Control Party.

The TACP Weapon System (TACP WS) is currently an element of the Theater Air Control system composed of small teams embedded into Army units from battalion to the corps level in order to advise ground commanders on air operations and provide terminal attack control of USAF close air support (CAS) assets.[17] As an Army Corps is usually the senior army headquarters (an ARFOR) inside a JOA [Joint Operations Area], the TACP weapon system integrates from the tactical to the operational level of War within a given theater.[18] Joint terminal attack control is "the authority to control the maneuver of, and grant weapons release clearance to, attacking aircraft."[19]

Since the TACP WS members wear USAF uniforms but work almost exclusively on behalf of sister services, it is inherently a joint warfighting community sitting on the seams of the service component's air-to-ground. Command and Control (C2) systems will play a significant, yet unrealized, role in JADO as an extension of the MDOC. Therefore, the existing JADO literature and academic commentary provide a framework for identifying how the USAF ground-based controllers will remain safe, relevant, and effective in the A2/AD environments of 2035 and beyond. This research investigates concepts derived from JADO's scholarly sources and adapts them to potential use cases for the TACP WS. A review of joint concepts and related literature establishes a baseline of joint expectations for command relationships, battlespace owners, and prioritization for all domain warfighting capabilities. Ultimately, this results in operational art in the conduct of JADO capabilities: the ways, ends, and means of JADO to

achieve A2/AD defeat; and the operational design or "the conception and construction of the framework that underpins" a counter-A2/AD campaign.[20]

Joint Publication 3-0 *Joint Operations* defines operational art as "the cognitive approach by commanders and staffs--supported by their skill, knowledge, and experience--to plan and execute (when required) strategies, campaigns, and operations to organize and employ military capabilities by integrating ends, ways, and available means."[21] This term traces its origins to German Unification wars, where military theorists saw a growing need to link tactical actions with strategic objectives.[22] The expanding size of armies and weaponry's lethality forced the geographic expansion of the battlefront and reserve forces' depth. Flanking and breaching the enemy's front became increasingly difficult unless coordinated temporally and spatially at scale. Thus, military theorists saw that "the planning and conduct of campaigns began to be based upon 'chunks,' or portions of the whole campaign," which are now termed "operations" in modern parlance.[23] Operational art "serves as the mediating, integrative synthesis standing between modern strategy and tactics."[24] Strategy frames the problem to solve, while tactics are the concrete methods to solve the problem. In simple terms, operational art translates "abstract strategic goals into mechanical terms [tactics] that commanders can then accomplish."[25] The Soviets who originally coined the term theorized that operational art reaches maturity when “The campaign and the operation would become a single entity through the linking of the initial and subsequent operations into a single unbroken operation that was extended both spatially and temporally so that it coincided with the campaign.”[26] Notionally, JADO attempts to link together an unbroken operation, extended spatially and temporarily, to produce multiple dilemmas for our enemies.

Status quo joint air-ground command and control systems featured in doctrine publications are insufficient to counter A2AD, which requires evaluation through the rubric of a refined JADO theory. DoD and congressional investments into JADO technologies reveal that joint, frame-worked prioritization is the answer to defeating A2/AD. Air Force JADO, Marine Expeditionary Advanced Base Operations (EABO), and Army Multi-Domain Operations (MDO) concepts will counter A2/AD because there is an expectation of jointness delivering coherent battlefield framework and optimal prioritization. The Joint Force requires a comprehensive, top-down, Joint All Domain Operations (JADO) theory that weaves across these emerging concepts, informing optimal JADO operational art and design. Armed with comprehensive operational art and design, the TACP WS will understand opportunity costs for employment and assess the consequences outside of their immediate purview while operating as a fail-forward C2 node charged with autonomous battle management of all-domain effects. The convergence of joint all-domain effects originating from all levels of operations and authorities in time and space allows the TACP WS to feed joint realities that will win the next War by allowing air power to remain the dominant arm of any fight now and in the future.

Joint All Domain Operations Service Concepts

Each service has derived its version of JADO implementation in the next 8-15 years: (1) The Air Force has Multi-Domain Operations Centers, (2) The Army has Multi-Domain Task Forces, (3) the Marine Corps has Expeditionary Advanced Base Operations.[27] It is beyond the scope of this paper to review each service's conceptual approach in detail. However, it is vital to establish a baseline of each service's concepts to compare, contrast, and identify the specific terms related to JADO command and control implications for the TACP WS.

Air Force

The 2015 *Air Force Future Operating Concept* details the transition from the AOC of 2015 to the MDOC of 2035. By the year 2035, the MDOC will become the operational-level "focal point for Air Force efforts to plan, task, execute, and assess missions as the Air Operations Center (AOC) did in the past" with "essential command elements and authorities to direct multi-domain operations."[28] The Air Force views the AOC's permanent, infrastructure-heavy basing as too static and at risk of kinetic or cyber-attack. In turn, MDOCs will be task-organized for repositioning, reconfiguration, or augmentation with geographically dispersed reach back cells supported by globally networked capabilities.[29] The MDOC will transition away from traditional 72-hour planning cycles in favor of "increasingly dynamic sourcing, tasking, and execution practices that operate inside adversary decision cycles."[30] Human-system interfaces and algorithm-driven networks will enable flexible planning and execution. Thus, Air Force operations will feature Adaptive Domain Control (ADC); forces perform sensor and shooter functions first to see, act first, and neutralize or kill an adversary.[31] If one domain becomes contested, forces will rapidly adjust efforts in other domains to achieve operational objectives.[32] These forces will take the form of manned, remotely operated, semi-autonomous, and

autonomous assets to deliver precise effects for missions ranging from strategic attack to CAS across the range of military operations.[33]

Thus, the Air Force has anticipated needed changes to feature adaptability in the next fight. However, it has yet to address how these decisions will impact future joint planning requirements outside of the air component. For instance, the land and maritime components have conditioned themselves to request support according to the AOC's 72-hour planning cycle. They craft requests for support following published theater Special Instructions (SPINS), Air Operations Directives (AOD), and associated planning timelines for the Air Tasking Order (ATO) to meet prioritization factors during time-bounded integration periods.[34] By doing away with a standardized, repeatable timeline to adjudicate requests on behalf of other components, the Air Force risks blurring an already challenging process to request air power. Entire theater air control organizations exist to implement the AOC status quo (see Figure 1), which will need significant alterations to evolve to more flexible and dynamic circumstances. The TACP WS is not immune to this change. TACPs are indoctrinated in the AOC's status quo planning cycles during formal training and are critical facilitators in execution.

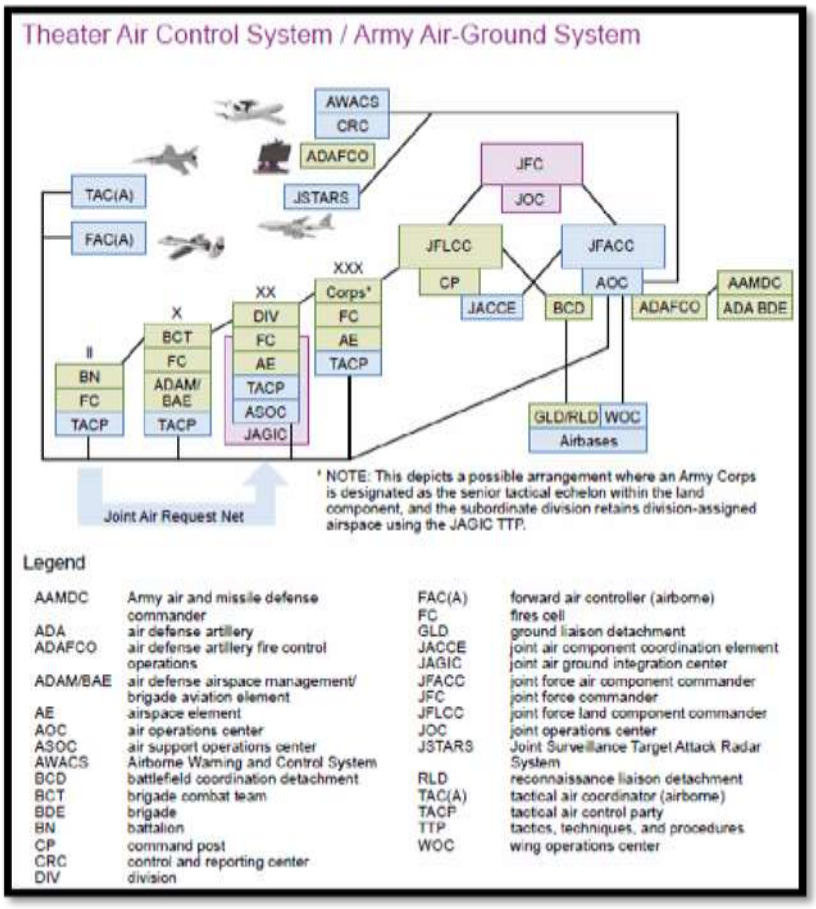


Figure 1. Theater Air Control System / Army Air-Ground System. Each acronym depicted represents specially trained personnel or organizations optimized to facilitate air-to-ground coordination.[35]

Furthermore, ADC may result in second-order effects in a hypothetical future fight. When the land component's TACP successfully bids for air support allocation in advance of a planned ground operation, air support is typically one of the land component commanders' critical requirements in their friendly center of gravity. However, if the air component makes rapid, algorithm-driven decisions to re-task airpower onto higher priorities, the Land Component might find itself unsupported. As a critical requirement, the decision to re-allocate air assets might force the Land Component Commander to reach no-go criteria for the overall mission. Worse still, if the Land Component is already engaged in combat, and the air gets pulled to another tasking, ground forces might face overwhelming odds and suffer high casualties in near-

real-time. If the Air Force's MDOC plans and ADC are not effectively communicated or do not fully consider the sister component's needs, this could lead to regression toward service parochialism and a loss of trust between joint forces.

Army

The Army's primary source capstone of Multi-Domain Operations is the December 2018 *TRADOC Pamphlet 525-3-1*. It calls for an evolution in the Army's ability to conduct Multi-Domain Operations (MDO) by 2028. Similar to the Air Force MDOC, the Army Multi-Domain Task Forces (MDTF) are "forward stationed formations able to execute aspects of MDO."[36] These organizations will deliver long-range precision strike, air and missile defense, electronic warfare, space, cyber, and information operations in both competition and conflict.[37] The intent is to provide the Joint Force and coalition with new capabilities to defeat A2/AD strategies; the Army views MDTFs as the forerunner to other multi-domain formations.[38] The Army's first experimental MDTF, in U.S. Army Pacific, leveraged numerous exercises and experiments throughout 2018. Exercises consisted of field artillery, intelligence, cyberspace, electronic warfare, and space capabilities that successfully linked systems and services across all domains, demonstrating a proof-of-concept for layered, non-kinetic, and kinetic effects against both maritime and airborne targets.[39] The Army terms these layered effects approach to warfighting as convergence, or the "rapid and continuous integration of capabilities in all domains, the EMS [Electromagnetic Spectrum], and information environment that optimizes effects to overmatch the enemy through cross-domain synergy and multiple forms of attack all enabled by mission command and disciplined initiative."[40]

Although the Air Force needs to expand and communicate its plans for JADO implementation to avoid the trap of sub-optimal future constructs, the Army appears ready for

change alongside its sister service. TRADOC notes that "currently, the Joint Force converges capabilities through the episodic synchronization of domain-federated solutions, but will have to conduct continuous and rapid integration of multi-domain capabilities enabled by mission command and disciplined initiative against near-pear threats in the future."[41] In turn, the pamphlet advocates for future upgrades in materiel, processes, and authorities to make joint frame-worked prioritization convergence a reality.

These upgrades include "a resilient technical architecture, flexible command relationships, and multi-domain control measures."[42] The technical architecture provides information flow between command centers, ships, aircraft, and units. Flexible command relationships allow the rapid relocation and re-organization of units across components for optimized force ratios and supporting fires.[43] The multi-domain control measures enable units to have exceptional latitude for cross-domain maneuver while mitigating safety issues with adjacent friendly forces when information flow breaks down.[44] In simple terms, these pre-established measures set the rules of the game for mission command across warfighting functions when communications fail.

As written, this strategy appears simple to implement; however, with each service pushing its agenda for a future JADO, one could expect the inter-service rivalry to disrupt meaningful progress. Additionally, unless supported and directed by the Joint Chiefs of Staff, the Army and Air force could be competing for the same tradecraft, creating redundant, organic formations that by nature require cross-function/cross-service expertise. The Army envisions algorithm-aided, rapid, decision making and flexible command relations; so too does the Air Force. This will require careful adjudication at the Joint Chiefs of Staff level to ensure an optimal solution for the final JADO framework.

Marine Corps

The June 2018 Marine Corps Warfighting Lab *Expeditionary Advanced Base Operations (EABO) Handbook* is a concept to drive force development and solicit ideas for further conceptual development on behalf of the Marine Corps within the next 5-10 years.[45] In summary, EABO is a future naval concept to defeat adversary counter intervention (A2/AD) by a low-signature, dispersed forward-basing infrastructure and force composition equipped with operational-level fire support platforms and limited sustainment.[46] Smaller autonomous platforms such as semi-submersibles and barges will mitigate sustainment challenges by loitering for resupply.[47] The Marine Corps intends to have Long Range Unmanned Surface Vessels (LRUSVs) in its fleet between fiscal years 2025 and 2027. LRUSVs are 11-meter-long autonomous and lethal connector boats capable of "cooperative swarming behaviors" and passing information to decision-makers seamlessly.[48]

EABO forces may consolidate within two proposed forms of Littoral Operations Areas (LOA); LOAs as a designated battlespace or LOAs as a permissive control measure under the direction of a Littoral Force Commander (LFC).[49] In this case, the theater Joint Force Commander (JFC) appointed a maritime area of operations, subdivided with subordinate LOA(s). The LOA(s) as a battlespace encompass landward and seaward littoral terrain for subordinate maneuver space, such as a maritime chokepoint or a littoral that enables the fleet's seaward freedom of maneuver.[50] As a multidomain control measure, the LOA allows the overall Composite Warfare Commander (CWC) or designated Expeditionary Warfare Commander (EXWC) to integrate his/her task group resources to achieve effects within the three-dimensional limits of the LOA and simultaneously support requirements from hierarchically adjacent warfare commanders.[51] If Marine or USAF TACPs align with EABO forces, the LOA as a multidomain

control measure will factor into airspace coordination for surface-to-surface and air-to-surface munitions. In turn, the LOA control measure will require an expanded definition in future iterations of Joint Airspace Control publications.

As in the Air Force MDOC and Army MDTFs, Marine Expeditionary Advanced Bases will require all-domain C2 strategies to enable employment of mines, sensors, flotilla forces, unmanned sensors and shooters, rotary-wing, land-based missiles, and non-kinetic capabilities.[52] Because of the proximity to long-range enemy artillery and other strike assets, all EABO C2 systems must have a low probability of detection and interception of communications. Furthermore, the C2 system must be service agnostic and enable full integration across the joint force in the air, land, surface, and subsurface.[53]

Alongside the Army's call for a resilient technical architecture, the Air Force's aim for an algorithm-driven global network, the Marine Corps' requirement for a service network fully integrated across the joint force might soon be a reality. A Congressional Research Service report from October 2020 outlines what Joint All Domain Command and Control (JADC2) is and how the concept is progressing. In the report, JADC2 is "the Department of Defense's (DOD's) concept to connect sensors from all of the military services – Air Force, Army, Marine Corps, Navy, and Space Force – into a single network."[54] Traditionally each service developed a tactical network for service-specific requirements, unable to interface with each other. JADC2 is a DoD-wide effort to develop a new C2 architecture to meet the National Defense Strategy demands of joint interoperability, and Congress is interested in footing the bill.[55] The House and the Senate authorized $144 million in fiscal year (FY) 2020 and the Pentagon seeks $302 million in FY 2021 for the project, as experiments in 2019 demonstrated the proof of concept.[56] Air Force and Navy aircraft, Army radars and mobile artillery, Navy ships, and space-based

collectors demonstrated "an ability to collect, analyze, and share data in real-time and provide a fuller picture of the operating environment to a C2 cell."[57]

During a TACP C2 Innovation Cell meeting in 2020, an officer embedded in the Joint Chiefs of Staff J6 staff noted that new technical architectures are advancing rapidly with promising results. This progress is good news, as the fail-forward C2 node for Air Force and Joint All-Domain precision strike, the TACP WS will undoubtedly be critical to input and consume data from JADC2 networks as end-users. If proven trustworthy through emergent practice and failsafe experimentation, TACPs will be more enthusiastic contributors to the Air Force's vision for ubiquitous sensor-shooter kill chains managed within the JADC2 construct. The USAF must prepare the next generation of TACP airmen now for the operational design of JADC2. Without TACP failsafe experimental and emergent practice with JADC2, the USAF risks the ability to sustain the convergence of all-domain effects in the nation's next war.

Justification for Change

Across the military diaspora, non-partisan think tanks, and members of the Armed Services Committee, there is a growing fear of the erosion of America's military superiority. When compared to neer-peer competitors, "the U.S. military could suffer unacceptably high casualties and loss of major capital assets in its next conflict."[58] The 2018 National Defense Strategy calls for the joint force to reorient on Great Power Competition, cautioning the possibility of employing Large Scale Combat Operations (LSCO) against an enemy of similar size, competency, and composition.[59] LSCO will require the U.S. military to operate "at a scale and tempo unlike any operation of the last three decades."[60] The compelling fear of losing the next war is the central theme of Christian Brose's, *The Kill Chain: Defending America in the Future of High-Tech Warfare*. It is also the preponderant driving force for change in the JADO primary source literature reviewed in Appendix 1. Brose sees the central concept to counter the adversary A2/AD as the reconnaissance-strike complex. He defines the reconnaissance-strike-complex as the confluence of emerging technologies that "enable militaries to build new battle networks of sensors and shooters that could close the kill chain more often and more rapidly than ever."[61]

Furthermore, the battle networks will "rely far more on advanced machines than on human beings," and that the new kill chains will "render many traditional military systems vulnerable and obsolete."[62] The situation may not be as dire as Brose believes. However, the joint force will need to change from how traditional military systems were employed in the past to ensure survivability in the horns of A2/AD. The likelihood of engaging with traditional Basic Fighter Maneuvers (BFM) into an A2/AD umbrella is unlikely for manned fighter platforms.

However, the same platform upgraded with new antennas and a commercially available tablet connected to advanced networks to control a swarm of drone wingmen is likely. The drone wingmen go in nose-first, engage, and defeat the enemy, vice the human operator him or herself. Drone wingmen fighting on behalf of their human controller is the intent behind Northrop's 15-year old program to build Distributed Autonomy/Responsive Control (DA/RC) unmanned planes like the Navy's X-47B project for autonomous attack or air defense.[63] The DA/RC concept translates to ground-based controllers conducting JADO at the edge of the battlefield, where the risk-worthy platforms assist in dismantling the horns of the A2/AD measures.

Air Combat Command's TACP C2 Concept of Employment specifies the Great Power Competition threat in the context of air-to-ground operations. The problem statement is "TACP C2 is not organized, trained, or equipped (OT&E) to be an extension of the AOC for the TACS/AAGS or as a forward node of JADO capable of employing Joint All Domain Effects in 2035 and beyond."[64] Here the Army Air-Ground System (AAGS) is "the Army's control system for synchronizing, coordinating, and integrating air operations with the commander's scheme of maneuver," the parallel air-to-ground fires execution system to the Air Force's TACS.[65] The document explains that ground maneuver forces and their supporting combined arms "will operate well within reach of long-range surface fires, advanced cruise missiles, hypersonic weapons, and space-based weapons."[66] Under an adversary's A2/AD umbrella, robust Air Defense Systems, Anti-Aircraft Artillery, Surface to Air Missiles (SAMs), and jammers will contest the USAF's ability to provide C2 to its forces. [67] The enemy of 2035 will also employ fixed/rotary wing aircraft and advanced standoff weapons against any force that attempts to breach mainland defenses. The enemy's capability parity in an A2/AD scenario like this is up for debate; however, the USAF plans to prepare for the most dangerous future reality.

Hypothetically, as a breaching (air, land, sea) force progresses from the 3rd to the 1st Island chain, the decisive advantage increasingly goes to China considering the Pacific Area of Responsibility (AOR).

Breaching the adversary advantage necessitates an expansion of TACP WS's capabilities and systems. The TACP WS will evolve traditional missions within the AOC hierarchy to the emerging MDOC construct, capable of "autonomous operations in support of the COMAFFOR [Commander of Air Force Forces] as a fail-forward C2 node of JADO (see Figure 2)."[68]

Figure 2. TACP C2 Operational Design. "TACP C2 in operational design sits at the tactical edge of the battle area and enables the execution of joint all domain effects. TACP C2 within the JADO enterprise enabling the C2 function for joint all domain effects and works in concert with the AOC and the U.S. Army's Multi-Domain Task Force (MDTF)."[69]

TACPs at the forward edge should exercise distributed decision-making ability and battle management authorities to create and execute force packages autonomously.[70] Distributed decision-making will be required if the COMAFFOR intends to use the TACP WS as a fail-

forward C2 node in the eventuality of an adjacent or higher echelon attack. The TACP must have the ability to act independently.

If approved, force package selection enables the TACP WS to execute convergent all-domain effects, which currently is maintained by an component-level TACS organization. To facilitate these requests and control the allocated force packages, TACPs will have nascent access to Advanced Communications Mesh Network, providing accompanying access to a Sensing Grid. [71] TACPs will be both a customer and a consumer of the sensing grid. An advanced communications mesh network creates a venue for "data distribution and information sharing within a battlespace, where each authorized user, platform, or node transparently contributes and receives essential information and is able to utilize it across the full range of military operations."[72] A Sensing Grid rides on the backbone of a mesh network and is "an assemblage of sensors, platforms, people, devices, content, and services that delivers a holistic, accurate, predictive, and timely characterization of the operating environment to decision-makers" (see Figure 3).[73] The emerging mesh network will allow the TACP C2 to communicate in contested electromagnetic conditions by autonomously rerouting communications traffic; it is one of the underlying technologies that enable ground-based controllers to remain safe, relevant, and effective in future battlefields.

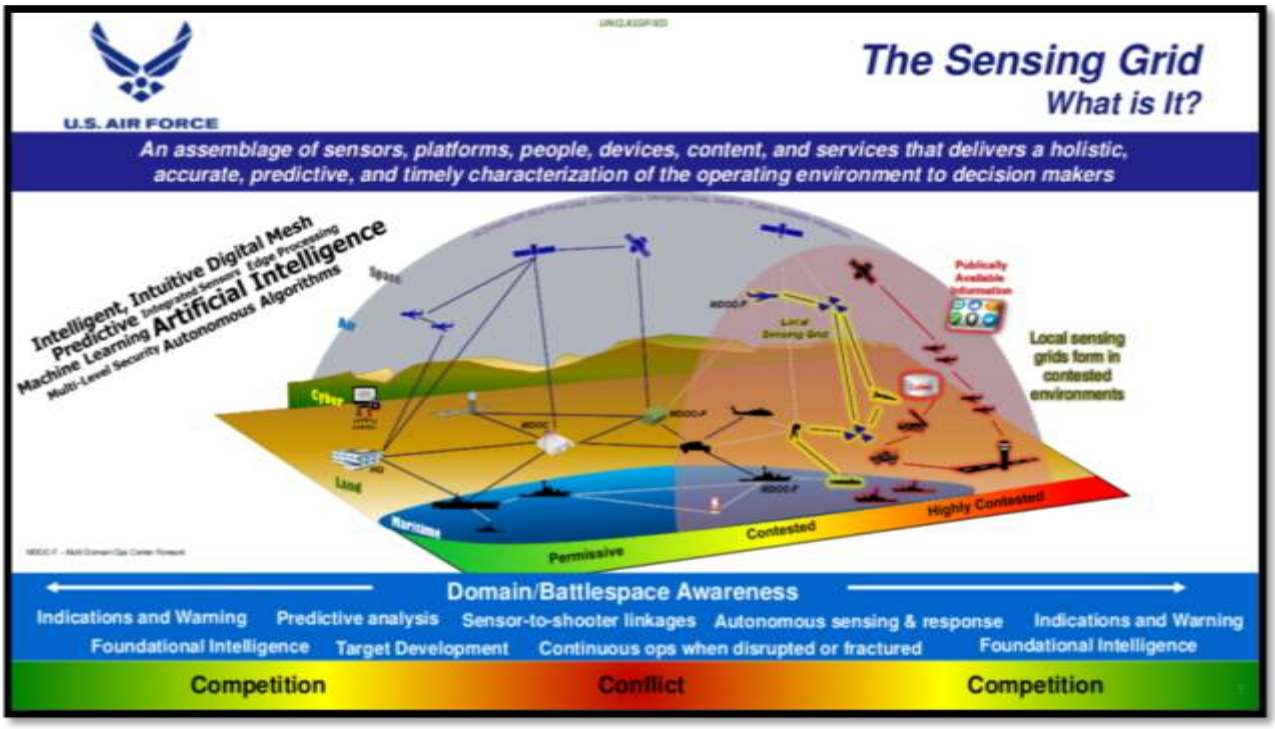


Figure 3. The Sensing Grid.[74]

The TACP WS will need to adopt a capabilities-based force provider model that differs from current static TACP constructs organized and constructed long in advance to achieve these expanded capabilities and authorities.[75] A capabilities-based model will allow TACP airmen to focus on learning emerging JADO skill sets and less on integration with traditional Army formations. The desired endstate would be "an all-domain minded force" beyond the scope of current formal training pipelines. TACP training would feature advanced systems training, classified facilities, higher security clearances, and distributed full-spectrum (air, land, maritime, cyber, space, electromagnetic) simulators.[76] In sum, the TACP WS becomes a full-spectrum effects controller, skilled in dismantling A2/AD defenses and restoring localized air supremacy to enable follow-on missions of close air support and air interdiction, for example. The TACP WS's upskilling must be informed by a comprehensive JADO operational design and forecasted tactical needs.

The status quo implications of the CAS mission are also in need of review in the context of JADO. In the March-April 2017 journal, *Military Review*, scholars considered CAS within the context of Multi-Domain Operations (MDO). MDO means thinking about problems in a non-linear way, achieving military objectives through seamless integration across the levels of warfare by leveraging each service component's unique capabilities absent of traditionally aligned domains.[77] Status quo joint fire support systems and supporting versus supported command relationships enable one service to cross warfighting domains with weapons effects in a supporting role.[78] The domain receiving effects is in a supported role. This process is far from seamlessly integrated and relies on a patchwork of line-of-sight and beyond-line-of-site radio or digital communications managed in part by the TACP WS, which are vulnerable to enemy and natural interference or obstruction.

Furthermore, the supported commander has designated air, land, or maritime battlespace in which he/she can determine when, where, and how many unique assets can be brought to bear or deny cross-domain access altogether. Even if the air component wants to provide legitimate Counterland effects on a designated target, it needs permission to employ outside of its designated battlespace. Once again, this example showcases the need to blur the lines of operational art and tactical needs across the air and land components inside of JADO.

The permission-based cross-domain operational design is not without reason, as "the authority and responsibility for the expenditure of any ordnance on the battlefield rests with the supported commander," which is an authority titled Target Engagement Authority (TEA) and delegated by the Joint Force Commander.[79] By separating battlespaces among geographically aligned TEA's, these authorities are able to accept risk that is directly affecting their own battlespace. This mitigates overall risk and increases situational awareness for each TEA.

Effects originating from the air or maritime domain could inadvertently commit fratricide and strike friendly forces in the land domain or vice versa if not sufficiently coordinated. Second, if ordnance drops within the boundaries of the supported ground commander's designated battlespace, the responsibility of the aftermath lies with that commander, regardless of whether or not that target was authorized. Retaliatory proportionality, civilian casualties, and fratricide are imperative considerations for eliminating cross-boundary restraints.

Nevertheless, this traditional way of warfighting compartmentalizes and isolates service capabilities within their assigned geographic boundaries. The operational design logically associates the Air Force with the air domain, the Army with the land, and Navy with maritime. This view impedes effective multi-domain operations since the land component adjudicates coordination of responsibility and authority for joint fires within its designated battlespace.[80] Proven and reliable JADO technologies or a comprehensive operational art/design reform must address the dilemma of adjacent geographic boundaries and competing airspace users.

Citing the example of Afghanistan, Tormey, Hendrickson, and Bartels stress in the March-April 2017 *Military Review* that land component's views of Close Air Support have become distorted and now amount to a protection category of joint functions.[81] Major Mike "Pako" Benitez confirms this sentiment in his War on the Rocks contribution, *How Afghanistan Distorted Close Air Support and Why It Matters.* From personal experience as an F-15E Weapons System Officer, he notes that "after years of fighting asymmetric low-intensity guerilla warfare, the Army began to request air cover as a preventive measure with the expectation of enemy contact" making it "common for aircrew to brief a set of missions, but execute none of them."[82] The Army essentially fostered "ground-directed dynamic targeting" for protection in reaction to enemy contact, rather than utilizing detailed integration, which is a defining and

necessary CAS characteristic. Detailed integration "describes a level of coordination required to achieve desired effects while minimizing the risk of fratricide—from either surface fires or air-delivered weapons."[83] Not only was the drive for self-protection frequently ineffective, but it was also dangerous for both members on the ground and in the air, featuring unbriefed or unscheduled aircraft flying through CAS airspace.[84] The vision of precise JADO technologies may enable future realities that mitigate the tactical need for human-led, permission-based, airspace deconfliction and friendly force battle-tracking.

Denigrating CAS to a protection category is not only the result of conditioning through dynamic, on-call support in Afghanistan; it is the byproduct of how the services view Air as a supporting function. Drawing attention to this issue is a tentative step toward understanding the need to blur operational art and tactical needs inside JADO. Airpower in the land domain needs to break away from this protection category of fires if the Joint Force intends to maximize flexibility, adaptability, effectiveness, and timeliness through the implementation of JADO. Close air support equates to life-saving kinetic effects to neutralize ground or surface-based enemies in its current form. It must evolve under JADO. With the fluid battlespace envisioned in 2035, an aircraft or swarm of drones may dynamically hunt the enemy, close, near, or far from friendly forces, all within the same sortie. To place it under a protection category of warfighting, aligned with a single battlespace owner, would limit the efficacy of the USAF's plan for adaptive domain control within JADO. This change means today's battlefield operational art and tactical imperatives get a needed evaluation and shift toward paralleling the two distinctions.

In the *Military Review* article, Tormey, Hendrickson, and Bartels point out that instead of time-consuming supported and supporting command relationship debates, multi-domain operations strive for the unity of command and effort through conceptual unity of thought.[85]

Each component commander will have to continuously visualize effects in air, maritime, cyber, and space and vice versa, which will minimize friendly vulnerability and will enable efficient means for timely exploitation of the enemy's weaknesses.[86] Thus, the American military as a whole must disaggregate C2 and push authorities to the lowest possible echelon to achieve faster kill chains. To avoid adversary exploitation at operational seams of air and ground, the authors, Tormey, Hendrickson, and Bartels, advocate for the lexicon to change from Close Air Support to Close Air Attack with an updated doctrinal approach for integrated and agile warfighting.[87] The authors adopted this idea from a Project AIR FORCE RAND study entitled, *Beyond Close Air Support: Forging a New Air-Ground Partnership*.

The basic premise of the study is to reimagine Counterland Doctrine to redefine its subsets of CAS, Strategic Attack, and Air Interdiction with "greater clarity, linking them unambiguously to the actual and contemplated actions of maneuver forces."[88] The study further argues that "in modern combat, air and ground forces increasingly operate in mutually enabling ways" and "air elements should be free to conduct deep operations against enemy maneuver forces, thereby isolating the battlefield."[89] Even if enemy contact occurs in close proximity to friendly forces, the ongoing refinement of aircraft technologies enables ground units to designate targets and confirm that no friendly forces are in the vicinity while being engaged.[90]

This proposed disaggregation of Terminal Attack Control functions rebrands Close Air Support as Close Air Attack. Although a trivial nomenclature change, it signals that Army and Air Force battlefield needs are equally important. It also inherits risk by federating tasks (target identification and friendly battle tracking) outside of the Terminal Attack Controller's job jar to less highly trained personnel or untested technologies. However, these proposed nomenclature changes and federation of duties allow controllers to focus on the highest priority targets

requiring detailed integration. It can only be achieved through a comprehensive review of Army and Air Force's respective TACS and Army Air-Ground System to enable battlefield decision-making below the component level.[91] Thus, status quo operational art for large-scale combat operations are in danger of eroding military success at the tactical level. JADO will need a supporting operational design template or the conception and construction of the framework that underpins a counter-A2/AD campaign.

Common JADO Enabling Concepts

Adaptive, Flexible, Forward Basing

The first common enabling concept across the three services is to have adaptive, flexible, forward basing options to complicate adversary targeting and enable survivability. In the July-August 2014 edition of *Air & Space Power Journal*, General David Deptula (USAF Retired) briefly describes the Air Force's successes in adaptive basing experiments under the "Rapid Raptor Concept." This idea includes four F-22 flights, and one C-17 mobilized on short notice to several distributed locations to conduct distributed control and decentralized execution.[92] In July 2020, the website *Stratagem* published an article discussing the potential of adaptive basing warfighting. The concept enables rapid deployment and resupply in A2/AD environments in contrast to maintaining large, centralized, infrastructure-heavy main operating bases that remain vulnerable.[93] In the Western Pacific Theater alone, over 150 island runways could support the forward deployment of artillery, fighters, and airlift assets. The European theater has limitless possibilities of remote highway stretches in any NATO partner's countryside.[94]

Given adaptive runway's potential, the joint force could generate forward, disaggregated, and untethered combat power. It could utilize airlift assets to supply C2 equipment, personnel, and forward re-arming or refueling points (FARP) for short, survivable durations, precluding preemptive targeting.[95] In addition to distributed FARPs and operating locations for fighter aircraft, one could foresee TACP members embedded in adaptive, flexible, forward bases as a force package to support fail-forward C2 missions on behalf of the MDOC.

Despite its amphibious nature, this concept is congruent with the Marine Corps' EABO implementation. In the EABO handbook, mobile EABs conceptually support expeditionary airfields, FARPs, and all naval aviation functions.[96] As the Warfighting Lab notes, this

effectively breaks the 'runway paradigm,' which is "critical to winning the hider/finder competition and to the continued utility of manned aviation as an inside force capability."[97] Here, inside forces mean persistent, low-observable, and risk-worthy capabilities living in EABs under the A2/AD umbrella to enable outside forces' maneuver. Again, Marine or USAF TACP members could embed with inside forces, operating from a forward location to control all-domain effects from an optimal observation post.

Mosaic Warfare

A second theme emerging across the literature is a theory of victory in A2/AD environments named Mosaic Warfare. This idea emerged from the Defense Advanced Research Project Agency (DARPA), in parallel to joint "service concepts like Littoral Operations in a Contested Environment, Multi-Domain Operations, and Multi-Domain Battle."[98] The general concept is to use cheap, fast, lethal, flexible, and scalable systems to swarm formations alongside other electronic and cyber effects to overwhelm adversaries.[99] Like mosaic tiles, any system can combine with others to form the desired warfighting capability synthesized with Artificial Intelligence-augmented C2.[100] The focus in mosaic warfare changes from the DoD's traditional attrition warfare approach to "making faster and better decisions than adversaries."[101] Here numerous autonomous systems employ within a disaggregated force design, enabled by Artificial Intelligence decision support tools so that commanders can manage rapid and complex operations.[102]

Army MDO, Marine EABO, and Air Force JADO emphasize distributed formations. However, the DoD still procures limited multi-mission platforms and troops without requisite decision support tools to enable distributed operations.[103] Mosaic Warfare could be the theory to compel the necessary procurement and operational design changes to support JADO. By

decomposing monolithic units into a large number with smaller functions, the DoD would establish a composable, mosaic force.[104] For example, a section of manned fighters exchanged for a fighter "acting as a C2ISR platform for a group of standoff missiles and sensor-and EW-quipped unmanned aerial vehicles (UAV)."[105] Ground units would feature smaller troop formations augmented by unmanned ground vehicles (UGV) and UAVs for self-defense, intelligence collections, and logistics.[106] This gamified operational design enables the commander to "direct the machine-enabled control system via a computer interface, assigning tasks to be completed and inputting estimates for the opposing force size and effectiveness."[107] The machine would identify "forces in communication that could be tasked" within the span of control of the commander, who would then choose the most profitable force package for tasking (see Figure 4 below).[108]

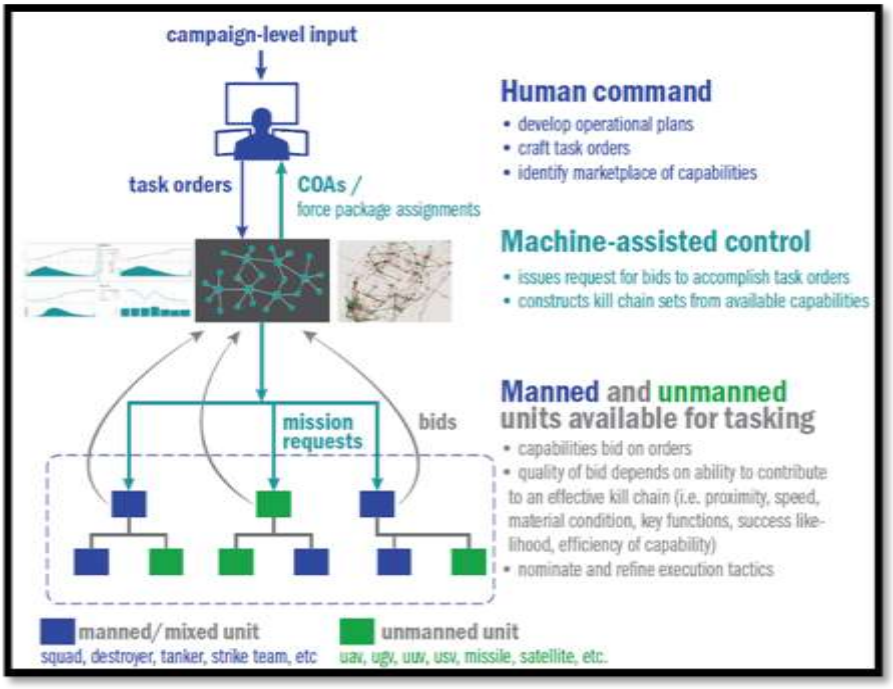


Figure 4. Mosaic Warfare Approach[109]

Through multiple wargaming iterations, DARPA found success in contesting near-peer competitors by using a risk-worthy force package of multiple unmanned assets serving as communications relays, jammers, or strike platforms. However, their success depended on an adequately trained force skilled in combined arms maneuver, advanced communications, and electronic warfare.[110] A multi-domain operational strategist at Air Command and Staff College, Maj Ernest Nisperos, similarly came to this same conclusion and advocates for a Joint Effects Convergence Team (JECT).[111] He proposes a new specially trained team, building upon existing TACS airmen's expertise, which complements JADC2's future tech. His solution could operationalize a Mosaic Warfare style of fighting. Much like TAC is a qualification that TACP members to apply control of airpower, the JADO equivalent would be a Joint-Domain Effects Controller (JDEC).[112] He noted that for successful convergence of effects across the six domains (electromagnetic spectrum, space, air, land, maritime, human), a team requires formal training and emergent practice to qualify members for mosaic warfare's delegated authorities and advanced technology.[113] This argument is similar to the training needs that the *Air Combat Command TACP C2 Concept of Employment* document envisions. Lastly, if JADC2 and Mosaic warfare are to be successful, he believes that "it is time to implement JADC2 mission functions commensurate with new technologies and rebalance C2 expertise across the joint force."[114] Again, the mosaic warfare team requirements add to the argument that JADO operational art and design are primary needs across the services to enable emergent practice and failsafe experimentation.

A third theme woven throughout nearly all service JADO concepts and commentary is the need for innovation in the realm of Artificial Intelligence and Machine Learning (AI/ML). If fully realized, AI/ML will be the cornerstone of JADO; it will 1) inform C2 decision-making

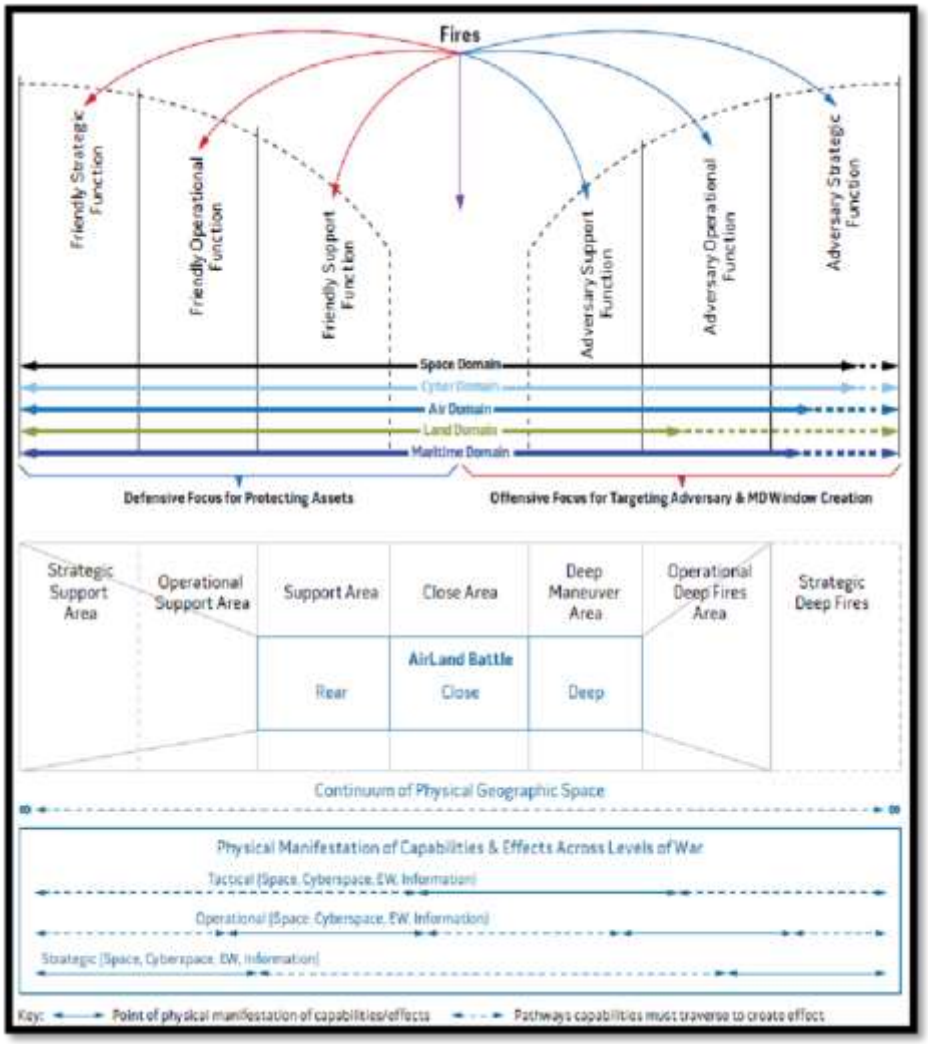
autonomy through emerging battle-management systems, especially concerning airspace and fires deconfliction and automated asset brokering 2) enable small, unmanned platforms to deconflict airspace, identify adversary targets and share information across a resilient mesh network, and 3) assist sensors in target recognition and weapons pairing across domains.[115] AI/ML is the proposed answer to mitigate problems inherent in JADO implementation. Riding on the backbone of the JADC2 network, it will synthesize human-machine teaming for optimal C2. Although it is a vital, nascent aspect of all the service concepts for future warfare, it is beyond this paper's scope to analyze further details. Nevertheless, AI warrants additional study and adoption by future JADO practitioners, namely the TACP WS. For a cursory explanation of AI and ML as it relates to JADO, see appendix 2.

Doctrine Reform

In *Joint Force Quarterly 88* from 1st Quarter 2018, Army General David G. Perkins and Air Force General James M. Holmes summarize the collaborative effort between Air Combat Command and U.S. Army Training and Doctrine Command to converge land and air domain capabilities for future multi-domain battle doctrine.[116] The authors note that although the Army orients its battlefield framework on forces and geography while the Air Force orients on functions and time, "there is significant room for convergence and integration between the two."[117] The generals add that the two services have collaborated heavily in the past to formulate the AirLand Battle Doctrine, resulting in experimentation, debate, and understanding of the post-Vietnam War battlespace.[118] The AirLand Battle concept was introduced and refined from 1982 through 1993, focusing on expanding the battlefield's scale, rapidly integrated air and ground maneuvers with requisite resupply to counter a potential Soviet attack.[119] Some would argue that the doctrine materialized the success of the 1991 Gulf War, with joint forces working in combined arms maneuver, enabled by deep battle air and ground integration, to defeat Iraq's Army.[120] AirLand Battle's success depended on force projection and pre-positioned war stocks, a single enemy and theater (Russia and Europe respectively), and a robust C2 infrastructure (now threatened by A2/AD).[121]

Today, JADO must also account for integrating new technologies in the cyber, space, and electromagnetic domain and a calibrated force posture enabling flexible, expeditionary response options across multiple theaters, rather than just one. The exact interplay of doctrine refinement between each of the joint forces can and must take hold today. Perkins and Holmes' collaborative contribution provides a practical visual framework (see Figure 5 below). It sets the example for Air Force and Army cross-domain functional teams to discuss the requirements to

operationalize JADO while mitigating inter-service rivalry. It generates conversation of shared expectations between the two services, which will enable forward-thinking on flexible command relationships, unity of effort, and unit of command; the operational art to translate abstract JADO



strategy into mechanical tactics.

Figure 5. Army–Air Force Battlefield Framework[122]

In consideration of Holmes and Perkin's article and the *TRADOC Pamphlet 525-3-1: The U.S. Army in Multi-Domain Operations 2028, a* July 2020 report published by a joint service team through the U.S. Army War College provides commentary on the similarities, differences, and areas for improvement in each Joint service's approach to the JADO concept. The authors use Perkins and Holmes' converged concept to describe seven contexts in which the joint force will operate in a future multi-domain battle (see Figure 5 above). The seven contexts include the Strategic Support Area, the Operational Support Area, the Tactical Support Area, the Close Area, the Deep Maneuver Area, the Operational Deep Fires Area, and Strategic Deep Fires Area (see Figures 6 and 7 below).[123]

Area	Characteristics with JADC2 Implications
Strategic Deep Fires Area	• Highly contested space requiring extensive planning to achieve convergence of all-domain capabilities from across and outside the theater • Operations in this area are typically politically sensitive • Episodic presence at time and place of joint force choice • Small scale of operations
Operational Deep Fires Area	• Highly contested space requiring convergence of more capable systems from multiple domains and across the theater • Operations in this area occasionally require high-level authorities or permissions • Episodic presence at time and place of joint force choice • Moderate scale of operations
Deep Maneuver Area	• Contested space with wide array of enemy sensors and shooters requiring signature management (particularly in maritime environments) • Requires significant allocation of resources and setting conditions to "break into" Deep Maneuver Area • Extended large-scale operations featuring both fire and maneuver make this a particularly fluid command environment that requires continuous reallocation of resources in response to changing battlefield conditions (opportunities, setbacks, and attrition)

Figure 6. Characteristics with JADC2 Implications 1.[124]

	• Information will be highly fragmented among echelons due to contested communications and enormous scale of information • Initiating contact will require significant all-domain capabilities from across theater, so will require JFC approval • Friendly forces have overall initiative, but persistent presence means that enemy forces will, at times, initiate contact on their terms
Close Area	• Routine condition for ground and naval forces, in which they have to rely mainly on organic systems and routine support from higher headquarters • Within range of numerous enemy sensors and shooters so signature management is important • Actions generally not politically sensitive or require closely managed resources so commanders can operate on their own initiative
Tactical Support Area	• Within range of many enemy sensors and shooters, so command decisions required to balance risk in protection with supporting forces forward.
Operational Support Area	• Operations entail extensive interaction with host-nation governments including intelligence, counterintelligence, transportation, and sustainment requirements. • Friendly operations entail risk to local populations.
Strategic Support Area	• Operations extend across geographic combatant command boundaries

Figure 7. Characteristics with JADC2 Implications 2.[125]

Based on the characteristics of the tactical contexts in Figures 5 and 6 and the converged framework in Figure 4, the areas for the greatest likelihood of the convergence of multi-domain effects will be the Tactical Support, Close, and Deep Maneuver Areas and therefore merit further consideration. Actions within the Deep Maneuver Area will signal the Joint Force Commander's operational decision to initiate a major effort, which will require large amounts of high-value all-domain capabilities.[126] The authors highlight that each context will require a unique, agile C2 solution based on friendly and enemy forces' relative strengths, the echelon retaining weapons employment authorities, and the operation's scale.[127] In great power conflict, each of the seven contexts will be resource-intensive, requiring various sensor-shooter packages at a single moment in time.[128] Unless each sensor-shooter pairing is a conscious decision to enable a larger

chain of tactical actions leading to an operational objective, suboptimal calculations will likely result from making decisions in a tactical snapshot at the lowest tactical level.

Additionally, if not united by an overarching operational art, adjudications for tactical sensor-shooter pairings cause inherent risk and indecision. For instance, immediate tactical action "X" might be more critical than "Y" to support the overall campaign, but inversely "Y" is more critical to one unit's survivability relative to the adjacent unit. Considering a tangible example, a special reconnaissance team with embedded TACP observe an adversary target of strategic importance and request all-domain assets typically reserved for operational or national-level objectives, such as hypersonic missiles or cyber-attacks. Expending a hypersonic missile or a single-use cyber-attack now makes the theater's joint force slightly more vulnerable for follow-on operations, as the stockpile of hypersonics is limited and cyber weapons can be single-use in some circumstances. Nevertheless, the effects were requested and executed at the tactical level.

For these scenarios, Clark, Broome, Franck, and Loftus propose a bare-bones operational design to address the capabilities allocation dilemma. Ideally, the operational design would feature "stewards" who own and sustain the capability and many potential "users" seeking to employ them. The idea is to create "large pools of all-domain capabilities aligned to some mission, function, or area, in which a single commander is both steward and user."[129] In this manner, the commander both sustains and uses all domain capabilities, enabling them to gauge risk and avoid trivial use.[130] Where the unification of users and stewards is not authorized or feasible, tactical users such as the TACP WS at the forward edge will require machine decision aids to "help them understand the opportunity cost for employment and assess the consequences outside of their immediate purview."[131] Both proposed courses of action erode the status quo

operational design entrenched in current doctrine. The prescribed frameworks espoused by current doctrine publications that favor the consolidation of forces by component (air, land, sea) will be ineffective, inefficient, or untenable for the execution of JADO if the union of stewards and users is the preferred solution. This would essentially require an overhaul of the TACS/AAGS, as the Army and Air Force forces would now be heirachically adjacent, flat organizations, supporting the designated steward. Thus the joint force will face fierce debates in the implementation of JADO, as entrenched tribes might see all-domain operations as one component robbing another's capabilities to solve its problems at the owner's expense.

Although the Army is pressing forward with its concept of MDO, retired Brigadier General Huba Wass de Czege (founder of the School of Advanced Military Studies and AirLand Battle author) offered an institutionally informed critique of the TRADOC Pamphlet 525-3-1.[132] He contends that JADO modernization initiatives are "too narrowly focused on physical and technological capability shortfalls" and that "they lacked vision based on a fuller understanding of technological potential, timeless applicable logic, and sound theory."[133] He further contends that the Army's version of MDO as a concept 1) does not articulate a well-developed theory of the problem, 2) fails to articulate a clear solution, 3) uses vague language such as “standoff” and “domain” that confuses understanding of the concept, and 4) its mission aim is too broad.[134] He concludes that MDO concepts need "a credible theory of victory-one that accomplishes the 1986 AirLand Battle's theory of victory for each offensive, whether overt or covert and subversive."[135]

General Wass de Czege's treatment of Army MDO is not unfounded and also applies to Air Force JADO and Marine EABO. As discovered in the literature, JADO, EABO, and MDO are solely concepts for technological linkages, not an all-encompassing general theory for countering GPC. Within the context of renewed Great Power Competition, the DoD is ripe for

expanding JADO or Mosaic Warfare into a concrete theory of what it truly entails, like those coalesced during the Cold War and the GWOT. Historical precedent tells us that a new war theory typically "emerges as a result of a combination of drastic changes in the international security environment, diplomacy, domestic politics, ideology, economics, and revolutionary advances in technology."[136] In its current form, JADOs proposed technological advances are not all-encompassing ends, ways, and means to defeat enemies in both competition and conflict. Instead of focusing on operationalizing the latest technologies, a refined theory should focus on defining, categorizing, explaining, connecting, and anticipating future war's infinite complexities supported by historical case studies.[137] This effort will ensure that the ensuing doctrinal upheaval and blurring of operational art and tactics is a necessary and well-founded cause in the pursuit of JADO implementation.

Whoever drafts this refined theory should shape a coherent narrative outlining basic concepts, "with a body of propositions, principles, and cause and effect relationships that generally holds true."[138] Selection of the author requires deliberation, as the author's affiliations and worldview will affect his or her ideas' credibility and reception.[139] An individual from within the DoD risks falling prey to tribalism, service advocacy, and compromising the final theory's objectivity.[140] These points lend to the argument that civilian academics need to contribute to the JADO body of literature. Civilian academics entrusted with theory development should not ignore or discard the current progress made in addressing the blurring of operational art and tactics to pursue effective JADO. The intent would be to flesh out a comprehensive explanation of what JADO is with service agnostic definitions and characteristics to inform operational art.

TACP WS Considerations

The analysis mentioned heretofore can ensure that USAF ground-based controllers will remain safe, relevant, and effective in the A2/AD environments of 2035 and beyond. When this happens, operational success is enhanced, and so too the continuation of U.S. battlefield superiority. With each military service hoping to participate in JADO, it appears the devil is in the details. Few service members have a holistic understanding of air, land, cyber, maritime, and space operational capabilities, let alone professional knowledge and qualification to employ them lethally. It is unclear in the literature for JADO as to whose needs get prioritized above others (E.G., Land Component needs vs. Air Component needs). Meaning, who decides when one bid for cross-domain support trumps another's to employ low-density, high-value assets? Also, who owns what battlespace, and how is it bound? Is it geographically or temporally bound? In an A2/AD fight, if the joint force resorts to status quo geographic JADO boundaries and command relationships, it falls back into the trope that CAS and ultimately airpower is a protection category of fires, not a mutually enabling battlefield function. Also, the military risks perpetuating convergence of capabilities "through the episodic synchronization of domain-federated solutions," which would be suboptimal for a future fight as previously shown.[141]

In a November 2020 *Breaking Defense* interview with the Chief Architect of Air and Space Forces, Preston Dunlap described JADC2 as "A Thousand Kill Chains in Your Pocket."[142] Access to the JADC2 architecture could come in the form of a handheld device, a tablet, a cockpit, a flying C2 platform, or a ground station with computers. Access will likely be widely proliferated and distributed since the Air Force's endeavors to use commercially available tablets and devices; the unique aspect will be the security guards and software loaded.[143] While

describing recent field tests, he noted that multiple military generals received a hands-on demo of the system in September 2020. The demo revealed:

> *The Power of an operations center into a handheld commercially available tablet, over a 5G tactical network, for the first time, that means literally the same software, the same data, the same decisions aids that were used by all the four stars back in the brick and mortar facility with the nice screens were in the palm of their hands and they could see each domain of the fight at the secret level of classification, over a tactical high speed network, with commercial security guards on top of it. - Preston Dunlap, Chief Architect of Air and Space Forces*[144]

Again, details matter here. What happens when an operations center's power makes it to the TACS's lowest echelon, the TACP fail-forward C2 node? As shown in the mosaic warfare section, AI and human teaming will undoubtedly need to filter, deconflict, and adjudicate requests from the bottom up. Authorities should be delegated, but what if numerous disaggregated forces from different services have access to the same hand-held operations center and request all-domain assets?

Although cheap, autonomous, or semi-autonomous drone killers with swarm behaviors should be available at the point of future great power conflict, will the density be sufficient for large-scale combat operations, and if so, who has control? The battlespace becomes convoluted, congested, and confusing, with multiple end-users demanding high-value, low-density kill chains. AI/ML brought to bear by JADC2 network linkages will, with high probability, be able to manage airspace, run asset brokering algorithms to resolve target/weapon system allocations. However, overall command responsibility is going to be challenging to address. The command dilemma is where emerging operational art/design and a joint, prioritized framework determine the strategic ends, ways, and means for regional/temporal and dynamic supporting and supported relationships. AI experts do not foresee human-level, machine intelligence reaching efficacy until nearly 2050 when it could actually solve complex apportionment decisions and rebalancing

cross-domain force ratios on a fluid battlefield unilaterally.[145] However, knowledge graph AI algorithms that link, align, generate, and analyze relational information built by ML digital modeling and simulations (coming within the next 5-10 years) will enhance human on-the-loop decision-making overall.[146]

Furthermore, all electronics emit a signature in the electromagnetic spectrum, which could be discovered and geolocated by an advanced adversary. This internet-of-things approach to sensor-shooter pairing will undoubtedly create a new and unprecedented level of emissions that the enemy will exploit unless properly mitigated through emission control protocols. What happens when these complex networks and advanced computing need troubleshooting on the edge of the battlefield? The TACP WS, as previously mentioned, will require revolutionary changes in its formal training pipeline to control all-domain effects. AI programming, troubleshooting advanced communications networks, knowledge of electromagnetic theory, and data science at the level on which TACP's lives depend incentivizes technical upskilling of the career field. To a degree, futurists see the growth of self-healing troubleshooting algorithms that gamify and simplify the advanced programming requirements of JADC2. [147] However, the TACP should prepare for the most dangerous scenario.

Upskilling the TACP WS through curated online courses could mitigate this issue. A similar effort for USAF Cyber and Space Warriors is the Air Force Digital University, an attempt to sharpen "the Air Force's cyber and technical workforce, then grow outward to all parts of the force to imbue digital literacy across the department."[148] The Air Force Digital University platform rests on existing Massive Open Online Courses (MOOCs), Udacity, and Udemy. MOOCs are currently under review as distance learning options for the next generation of U.S. Special Operations Forces training. The idea is to use the platforms to host the Joint Special

Operations University curriculum to federate to operational forces.[149] Courses available on the platform already hail from Ivy League Universities, Silicon Valley industry experts, and elite computer engineers and programmers. Thus, one solution is to leverage Air Force Digital University to provide curated AI/ML, Data Science, Electromagnetic Theory, and Web Cloud management curriculum for an initial cadre of future JADO TACPs. This initial cadre could receive hands-on application and evaluation by contributing to JADC2 development at the Air Force Research Laboratory.

Online distance learning only provides one answer to the more substantial issues facing the TACP WS in executing JADO in the battlefields of 2035 and beyond. Based on available material, this paper captures the immediate need for technologically upskilling TACPs, increasing security clearance privileges, codifying the TACP Weapon system's role in JADO, and encouraging additional study. For example, conduct a study investigating formal training changes to prepare the TACP WS for Joint All Domain Effects Convergence. Particularly in the fields of cyber and electronic warfare weaponeering, advanced networking courses, and unilateral shoot, move, and communicate skills optimized for A2/AD operating environments. Furthermore, future studies or concepts should propose operational design or technological solutions to the following complications created by the JADO concept:

1. Multiple end-users with unprecedented access to competing for cyber, space, air, ground, and sea-based kinetic/non-kinetic effects
2. Increasing difficulty in disguising physical and digital signatures of forces arrayed on the battlefield
3. Uncertain command relationships, battlespace owners, alignment, and weapons release authorities
4. Complicated prioritization decisions of current and emerging unmanned asset's allocation

Clark et. Al reached a similar conclusion in *Command in Joint All-Domain Operations Some Considerations,* as discussed in the doctrine reform section. Addressing the four complications above and the formal training deficiencies will build trust in the way ahead for JADO and enable emergent practice and failsafe experimentation across world-wide TACP formations. Allowing the TACP to utilize emergent practice and failsafe experimentation with emerging JADC2 technologies will help drive one piece of the puzzle, evaluating the tactical needs of JADO against its operational design. Refining the JADO theory to the degree that Wass De Czege calls to action (defining, categorizing, explaining, connecting, and anticipating future war's infinite complexities supported by historical case studies) is another. These actions need to take place in parallel in order for the TACP WS to realize how to stay safe, relevant, and effective in future combat.

Conclusion

The Army, Air Force, and Marine Corps are developing a patchwork of service-derived conceptual solutions to China and Russia's emerging competitive advantages in A2/AD. China and Russia's A2/AD functionality threatens the U.S. Military's ability to project power globally and decisively win engagements. There is a component of legislators, think tanks, defense strategists, and military leaders who share the fear of losing the nation's next battle as a result. The answer to this fear is that the U.S. military must evolve from acquiring parochial, exquisite military equipment to a networked approach of existing sensors and shooters enabled by AI/ML and low-cost, unmanned, risk-worthy platforms.

Successful JADO will present multiple dilemmas inside the adversary's decision cycle, disrupting their ability to block land access. This success hinges on a viable theory of victory, a more thoroughly defined strategy for offense, and less confusing terminology that obscures progression across the joint force. The theory must be reinforced by a comprehensive body of propositions, principles, and cause and effect relationships between the joint services. Without a concrete JADO theory, bottom-up approaches from each of the services will lead to suboptimal conditions in the future. This suboptimal future state is already evident in the unending series of new acronyms to describe processes, concepts, and technologies. Few sources cited in this paper share the same taxonomies of the aspects of JADO, even when the authors are from the same military service.

Additionally, joint services must test and experiment with adaptive basing concepts and set functional AI/ML conditions to enable C2 and sensor-shooter advantages with requisite evolutions in data structuring. Adopting JADO technology needs to be tempered with realistic

expectations and alternative strategies for when it fails or when successfully attacked by the enemy.

Following U.S. Army TRADOC and Air Combat Command's example to build a collaborative, cross-functional framework for JADO, the joint force needs to investigate and understand how to build a joint effects convergence team to execute mosaic warfare or similar warfighting concepts. This demand melds operational art and tactical imperatives together like never before. The need to conceptually mandate distinctions between these levels of War may well persist, but that need is joined by dynamics pushing such delineations to the sidelines. In this tension lies future war success for the U.S. military. In many ways, the armed forces are going in this direction. More can be done. The services must begin to discuss the complexities of the seven tactical contexts of Multidomain Battle since they will inform requirements and decisions for all other aspects of JADO. These seven tactical contexts drive a conceptual framework for critical thinking in the realm of agile command relationships, weapons release authorities, communications plans and disciplines, and high-value all-domain asset apportionment. Finally, the Army, Air Force, and Marine Corps need to conduct a comprehensive review of existing doctrine for the Theater Air Control Systems, Army Air-Ground System, and the Marine Air Command and Control System, informed by a refined theory of JADO and in full consideration of blurring lines of operational art and tactical realities.

Given the deficiencies above, the services are pressing forward in developing a potentially game-changing capability. Theory development, doctrine rewrites, and training instructions require much time to implement across a massive bureaucracy. The DoD cannot afford to stop military adaption in the face of an emerging threat while seeking the perfect solution. JADO advances move the services in a helpful direction to keep airpower dominant; comprehensive

reform to the status quo operational art needs to be developed in parallel. The real difficulty may be in adapting, discarding, or revolutionizing entrenched service tribes and systems to meet new demand. The services must all look introspectively, determining if they are looking at these technologies' strategic-operational impact and how warfighting needs to change to take the most advantages. As in all civ-mil relations, civilians have the constitutional authority to drive military policy. In turn, civilians need to engage in JADO discourse beyond Senate and Congressional JADC2 funding authorization hearings. They need to set policy and help create an all-encompassing strategy for conducting war in competition and conflict against our emerging near-peer threats.

The TACP WS is a critical node of the Theater Air Control System, historically providing air operations advice and terminal attack control of CAS assets in close proximity to friendly forces. The revolution in JADO concepts makes Close Air Support's future role uncertain by 2035. Given that the TACP is currently an extension of the AOC and the AOC will become the MDOC, TACP C2 should be a fail-forward extension of C2 for JADO effects. As discussed in the previous section, JADO drives numerous complications for the Air Force's ability to provide joint lethality in the form of a kill chain. These issues require further study to provide comprehensive solutions.

Regardless, the TACP WS is uniquely positioned to answer these challenges head-on as one of the few communities in the DoD that inherently is trained to control all-domain joint force capabilities as Joint Terminal Attack Controllers. The TACP WS can be augmented, re-organized, and retrained to support all-domain operations regardless of its supported commander's service. In turn, the USAF TACP WS will feed joint realities that will win the next war by allowing air power to remain the dominant arm of any fight now and in the future.

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Appendix 1: Literature Review

Except for Christian Brose's book, *The Kill Chain: Defending America in the Future of High-Tech Warfare*, there is an absence of civilian academic literature analyzing the DoD-wide efforts to implement JADO. Brose tries to spur a revolution in the DoD's antiquated weapons procurement process, battle network connectivity and embrace Silicon Valley's expertise by presenting sample cases of the possible solutions to counter Russia and China's emerging A2/AD capabilities. He bemoans the gridlocked military-industrial complex that has consolidated into a handful of private military contractors incentivized to minimize competition, sell unsustainably exquisite and expensive, proprietary systems that receive untimely incremental updates. Brose explains that instead of changing in light of adversary countries' revolutions in military affairs to counter the U.S. hegemon capabilities, the Department of Defense has doubled down on amassing newer versions of traditional airplanes, ships, and armor instead of "smaller, lower-cost, expendable, and highly autonomous machines."[150] He highlights that the Silicon Valley and the Department of Defense have great mistrust in one another, dampening the potential for importing Silicon Valley's innovative approaches and brain trust with open-ended software updates and 'internet of things' connectivity in military hardware.[151]

Brose draws numerous comparisons between the computing power in modern commercial devices and military hardware that show U.S. military capabilities are far behind the technological power curve. The lack of connectivity and bandwidth between proprietary systems, he believes, make the ubiquitous battle network of sensors and shooters and the potential of Artificial Intelligence-aided decision-making nearly untenable.[152] He explains that U.S. military systems and warfighting concepts are almost self-optimized for enemy targeting since adversaries such as China and Russia have been developing countermeasures for nearly

three decades to target large exquisite systems.[153] Brose's advocacy has successfully permeated military circles, including the Marine Corps Warfighting Lab, and most certainly influenced the 22nd Chief of Staff of the Air Force, General Charles Q. Brown Jr., impacting his *Accelerate Change or Lose* strategic policy paper. General Brown generally comes to the same conclusions and spurs USAF innovation through rapid prototyping inside competitors' fielding timelines and divesting sacred cows.[154] The influence of Brose's work should serve as an example for other civilians to adopt, as his commentary provokes effective change outside of military silos and solicits private industry support and innovation on behalf of the DoD.

Additional material reviewed for this analysis consists of military sources, doctrine publications, and conceptual reports. For example, the *Expeditionary Advanced Base Operations (EABO) Handbook*, written by Art Corbett of the Marine Corps Warfighting Lab, attempts to inform Marine Corps force design and operational art for A2/AD environments; it is an iterative document and open for debate.[155] In the course of writing this thesis, the *Tentative Manual for Expeditionary Base Operations* was published in February 2012, which further refines planning considerations beyond the initial Handbook. Another primary source document, *TRADOC Pamphlet 525-3-1, The U.S. Army in Multi-Domain Operations 2028*, describes how the Army deters and defeats A2/AD adversaries using "three interrelated tenets: calibrated force posture, multi-domain formations, and convergence."[156] In addition to General Brown's, *Accelerate Change or Lose*, the Air Force has published several JADO conceptual pieces sponsored by the previous Chief of Staff of the Air Force (General David L. Goldfein) and whitepapers published by retired Generals through the Air University at Maxwell Air Force Base. These pieces are part of a growing body of USAF conceptual frameworks detailing the USAF's contribution to the Joint Force's JADO initiative. The topics coalesce around revolutionizing command and control,

adaptive basing, expanding weapons networks, and the ubiquity of unmanned-manned sensor-shooter teams undergirded by human-machine optimization through AI More specific to the research of JADO and the USAF TACP WS is the *Air Combat Command Tactical Air Control Party Command and Control Concept of Employment* paper, which frames the mission, functions, and capabilities of the TACP WS at the operational level in the context of A2AD environments in 2035 and beyond.[157] Backgrounds matter here; in each case, the experts are high-ranking retired or active-duty military officers and their staff officers located at service-level training and doctrine commands speaking to needed expertise but also the narrowness of the analysis—which to date remains predominantly military-centric.

All scholarly commentary of JADO concepts are composed by military-influenced, albeit non-partisan think tanks or PME war colleges. For example, Huba Wass de Czege of the Strategic Studies Institute provided a critique of *The US Army in Multi-Domain Operations 2028*. He agrees that the United States has "significant challenges in deterring either Russian or Chinese aggression."[158] Wass De Czege believes that the DoD modernization efforts to counter A2/AD with JADO are "too narrowly focused on physical and technological capability shortfalls," lacking "a fuller understanding of technological potential, timeless applicable logic, and sound theory."[159] In turn, he advocates for a departure from "old tactics with new technology" to "a highly integrated multidimensional operating approach of new tactics and strategies."[160] Four Colonels in the Carlisle Scholars Program of the Army War College, representing the Army, Air Force, and Marine Corps, also make the case that JADO needs to go beyond technical linkages between sensors and shooters, emphasizing the need for operational art of command considerations in JADO as well. In their estimation, service JADO concepts fail to address "the issue of command, who decides when and where to employ capabilities in both

space and time, as well as when and where to accept risk."[161] This shortcoming could lead to "incremental bottom-up decisions based on purely tactical and technical considerations trapping the joint force into a sub-optimal future form."[162] Here, tactical requirements and strategic imperatives will fail to mesh effectively, leading to difficulties in future mission execution.

JADO wargames and exercises are ongoing, but scholarly summaries of lessons learned from each are either limited or not discoverable on internet-based libraries. In one case, from December 2019 to January 2020, The Air Force Institute of Technology studied the implementation of Battlespace Next (BSN), a collectible card game to teach 103 joint-military human subjects Multi-domain Operational concepts and facilitate discussion on advancing JADO strategy.[163] BSN educates players on advanced cyber, information operations, and electronic warfare capabilities' convergence with conventional military capabilities in a JADO environment, encouraging players to develop innovative strategies for victory.[164] BSN endeavors to enhance learning on JADO and drive transformational approaches for warfighting practitioners in A2AD environments; the study's observers documented efficacy through playtest improvement in military readiness across several areas related to A2AD. Another such effort is the Army's "capstone multi-echelon live and constructive exercise," the Joint Warfighter Assessment.[165] The first iteration, JWA 18-1, held between 27 April and 10 May 2018, assessed the JADO concept's execution, integrating joint and multinational partners across multiple warfighting echelons and functions, to solve critical problems of A2AD.[166] Both wargames attempted to teach practitioners the concepts of JADO and add to the body of lessons learned to improve technology, concepts, and force design.

Since JADO concepts are still emerging, the non-availability of civilian sources is understood and is limiting in some respects. The ongoing military effort would benefit from a

civilian critique. For this reason, this thesis advocates strongly for more civilian academic perspectives in the future.

The TACP C2 Innovation Cell, a disaggregated grouping of career TACP personnel with placement across Air Force Major Commands, Headquarters Airforce, and the Joint Staff charged with JADC2 testing and evaluation, agreed to contribute to this study by providing cutting-edge literature and feedback. On 19 November 2020, the Cell met with the author for a virtual discussion focused on this thesis. Participants provided literature on emerging JADC2 network architecture, additional RAND JADO studies, white papers, and more current literature on enabling concepts such as mosaic warfare.

Lt Col Erik Haeuptle, a USAF officer on the Joint Staff, directly charged with coordinating JADC2 network architecture across the services, commented that the JADC2 initiative is progressing faster than doctrine can codify, adding that services that act parochially will be left behind. This point drives home the case for dynamic and living doctrine vice the traditional and static-reactive doctrinal cycle that currently drives military development. If the DoD envisions dynamic and adaptive systems that undergird JADO, it will need dynamic and adaptive strategies and doctrine as well.

Furthermore, in light of JADC2's rapid evolutions, participants called for this study to advocate training expansion for TACP WS operators, specifically in the cyber domain. The emerging technological framework will require TACP WS operators to troubleshoot advanced networks, unmanned systems, databases, and protocols that are far beyond the scope of current training. Training and maintaining a balanced and elite level of cyber, air, and ground maneuver competencies will likely prove problematic, yet technological solutions such as "gamifying" or simplifying end user interfaces might assist in the cyber realm.

Captain Todd Graff, the Air Force TACP C2 Innovation Cell Lead, agreed to collaborate throughout thesis drafting. This collaboration featured web-based virtual chat and information sharing discussions focused on JADO force development and experimentation for the TACP WS. As the TACP C2 Innovation Cell lead, Captain Graff has access to key leaders and decision-makers across the global USAF TACP Community. He is conducting a three-year experiment on the manning, technology, methods, command relationships, and equipment necessary for the USAF TACP to conduct JADO in future battles. His research will culminate in a capstone essay to document his research and provide recommendations for future Special Warfare C2 task organization, training, and equipment.

Based on available material, this paper captures the immediate need for upskilling, increasing security clearance privileges, codifying the TACP Weapon system's role in JADO, and encouraging additional study. For example, a sponsored study to investigate changes required in Formal Training to prepare the TACP WS for Joint All Domain Effects Convergence. Particularly cyber and electronic warfare weaponeering, advanced networking courses, and unilateral shoot, move, and communicate skills optimized for A2/AD operating environments. Furthermore, future studies or concepts should be developed to propose operational design or technological solutions to the following complications created by the JADO concept:

1. Multiple end-users with unprecedented access to competing for cyber, space, air, ground, and sea-based kinetic/non-kinetic effects
2. Increasing difficulty in disguising physical and digital signatures of forces arrayed on the battlefield
3. Uncertain command relationships, battlespace owners, alignment, and weapons release authorities
4. Complicated prioritization decisions of current and emerging unmanned asset's allocation

Addressing the four complications above and the formal training deficiencies will build trust in the way ahead for JADO and enable emergent practice and failsafe experimentation across world-wide TACP formations.

Appendix 2: Artificial Intelligence Primer

A 2020 RAND Project Air Force studied and recommended opportunities for applying Artificial Intelligence (AI) to Joint All-Domain Command and Control.[167] One of the report's key findings is that although AI/Machine Learning (ML) was proven successful in defeating world champions in games such as Go, no-limit poker, and StarCraft, the AI was built from ML on curated examples in a training set.[168] In other words, AI/ML requires structured data as examples to know how to make or present informed decisions. The Joint force must implement and invest in 'data lakes,' which will process data into a useable format to enable AI/ML.[169] MITRE Corporation Data Scientist, Conor Mahoney, notes that this is where Model-Based System Engineering and advanced modeling can provide great utility in assisting wargame machine learning.[170] Model-based systems engineering enables true-to-life "Digital Twins" based on painstakingly detailed schematics of existing or emerging warships, plans, vehicles, and weapons.[171] These digital twins go to war with the enemy inside an advanced simulation, resulting in machine learning and artificial intelligence insights to assist decision support in the future. These simulations are ongoing, and Mr. Mahoney notes that "by generating synthetic data inside an environment that can pre-train a base AI system that could then be employed in parallel with legacy systems in the real world until it reaches an optimized and useful state."

The proposed advancement of AI represents a long-term strategy and will need advocacy from the Joint Chiefs of Staff to implement across all service domains. The Air Force intends to be the Joint Service forerunner on this effort by providing an architecture to build AI/ML. Given the service's technocratic-focused acumen, the USAF leads again, as it did with cyber and space forces. Advanced Battle Management System (ABMS) technology evolved from a need to

replace the E-3 Airborne Warning and Control System and the E-8 Joint Surveillance Target Attack Radar System; it will become an "internet of things" for the military.[172] ABMS will serve as the technical backbone on which AI algorithms can flow seamlessly. ABMS will accomplish numerous JADO functions, including 1) enabling automated operations for low-cost, risk-worthy drones, like the XQ-58A and X-61A, 2) integrating various sensor feeds across multiple domains via desktops, virtual reality, and touch tablets, and 3) ensuring survivable C2 functions to various deployed, distributed nodes.[173]

While data-driven technology has impacted the battlefield, here is a note of caution not to pay too much credence to machine-enabled functionality. Many AI experts urge caution in overestimating its capabilities. Ben Lorica and Mike Loukides, two AI practitioners, discuss the current state of affairs and AI limitations in *What is Artificial Intelligence.* Lorica and Loukides claim that AI is narrow in its application; it is "still fundamentally a question-and-answer machine that must be tuned to a specific domain."[174] They continue that "you can add narrow AIs ad infinitum," but "a pile of narrow intelligences will never add up to general intelligence."[175] Narrow AIs are programmed algorithms to perform functions within a clearly defined domain, unable to achieve human-level creativity. At this point, AI practitioners have yet to find a master algorithm for AI that can solve problems beyond the analysis of the curated data set it is programmed to analyze within the boundaries of its data storage bin. Therefore, AI will likely continue to be a highly supervised process, lacking the ability to perform human-level, machine intelligence functions beyond navigation and "specific tasks like speech recognition, image classification, and of course, game playing."[176] A survey of experts suggests higher functioning intelligence will occur with a 50% probability somewhere between 2040-2050, far later than the current JADC2 demand for AI adoption as a critical enabler within the next decade.

Even if AI technology advances exponentially under an unexpected timeline, extensive reliance on AI to inform decision-making can cause dangerous consequences. AI is vulnerable to new attacks, such as Input Attacks or Poisoning Attacks in the physical and cybersecurity realms, which are already here.[177] Input Attacks manipulate "what is fed into the AI system in order to alter the output of the system to serve the attacker's goal" while Poisoning Attacks corrupt "the process during which the AI system is created so that the resulting system malfunctions in a way desired by the attacker."[178] An input attack, in particular, is simple, cheap, and risk-worthy. A savvy attacker could alter the physical characteristics to trick the AI system into observing something different or not sense anything at all.[179] If the alterations are inconsistent with the programmed variations in the AI data set, the system might see balloons when there is a tank within the crosshairs of an autonomous sensor.[180]

This deception is the equivalent of modern age denial and deception techniques adversaries may employ to counter AI advantages. The best answer to this is the retention of human-in-the-loop analysis for critical operations support and logic-based systems that cue follow-on analysis either via an algorithm or a trained analyst. The TACP WS has substantial collective experience in the observation of senor footage and imagery within a kill-chain making yet another reason the community should be at the forefront of JADO innovation. In the case where AI says there is a tank on the side of the mountain or identifies any sort of anomalous data given the operational characteristics of said tank, and then either run further analysis across different sensors or sends it to a human for further review. As it stands now, critical JADO AI/ML advances in Edge AI, algorithms deployed to edge devices to enable military Internet of Things interoperability, and sensor exploitation without access to data centers is two to five years

away.[181] Knowledge graphs, the AI algorithms that link, align, generate, and analyze relational information, the battle management support are five to ten years away.[182]

Appendix 3: Endnotes

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