5G & Edge Computing: The Future of the DoD and JADC2

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Introduction

In December 2020, the Secretary of Defense published the "Department of Defense 5G Strategy Implementation Plan." Within it, the Department of Defense (DoD) describes the importance of integrating 5G and edge computing into military operations, primarily for its higher performance, data-driven applications, and machine-to-machine communication. The strategy provides a baseline roadmap for development, experimentation, and prototyping 5G capabilities while ensuring the DoD will facilitate the advancement and adoption of 5G technology.[1] This plan stresses the importance and emerging capabilities of the technology as well as on-going efforts with endless possibilities for implementation. However, 5G and edge computing can achieve much more. It is key to the military's concept of Joint All-Domain Command and Control (JADC2) by greatly improving areas of command and control (C2), logistics, future weapon capabilities, and implementation into large scale combat operations.

As the National Defense Strategy guides the joint force towards an environment of great power competition and defending the nation against near-peer adversaries, the concept of JADC2 has become the cornerstone to unifying networks, sensors, and weapon systems to distribute information across services, commands, decision makers and warfighters.[2] JADC2 facilitates the unification of efforts across all domains to exploit the advantages of joint and partner nation capabilities, providing mission commanders an ability to rapidly develop, execute, or transition between kill chains to overwhelm adversary defenses and present the enemy with multiple dilemmas.[3] Figure 1 shows the JADC2 Placemat and how all domains must mesh into a 'Warfighting Network' that fuels the decision cycle.

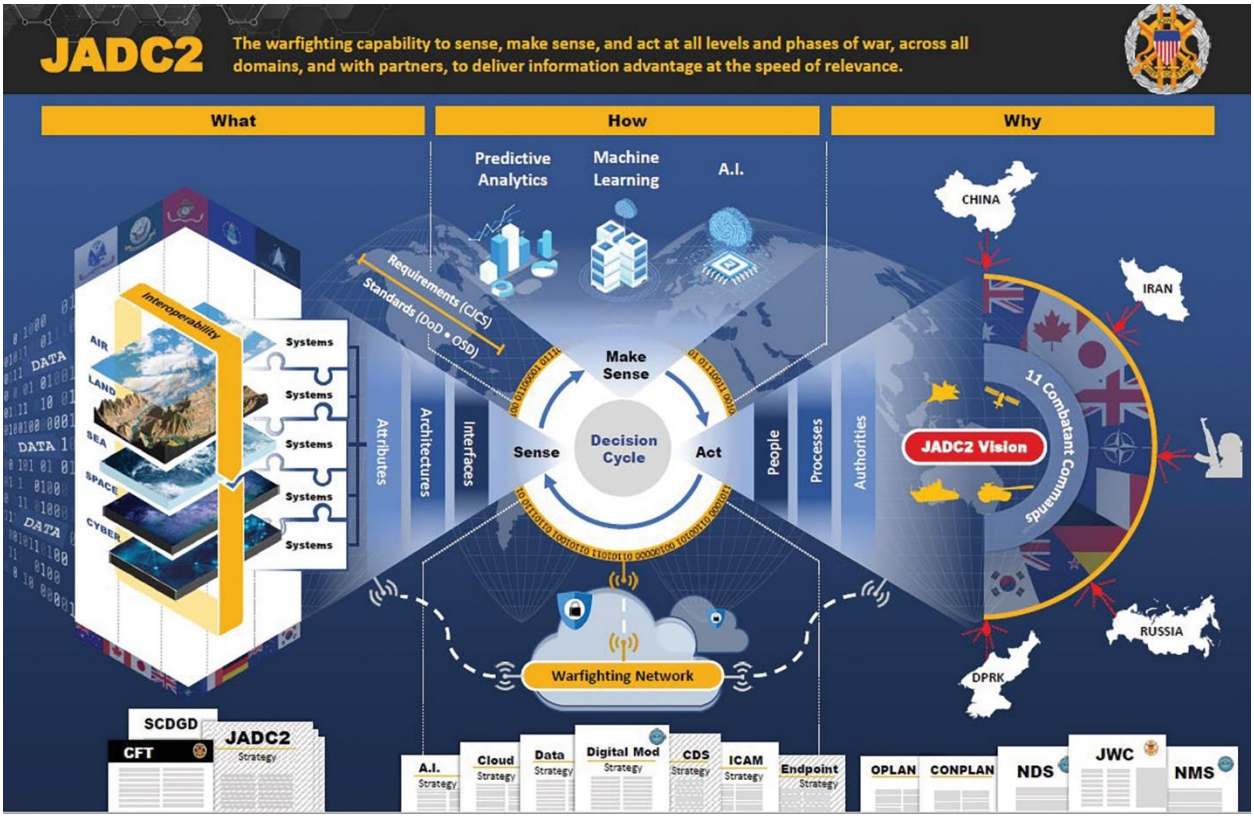

Figure 1: JADC2 Placemat[4]

Additionally, the Air Force has undertaken the concept of agile combat employment (ACE) to counter threats and mitigate challenges in the pacific theater. Our nation has moved into the far realm of great power competition and commanders need the capability to make near instantaneous decisions based on empirical data in real time. More importantly, warfighting information and targeting data must be seamlessly shared between disparate individual platforms as well as entire units. We have begun to develop the solutions needed to achieve interoperability across disparate systems and waveforms through the development by warfighters at the tactical edge of the fight; indeed, where this innovation is most in need.[5]

Systems such as the Automated Tactical Targeting and Counter-Fire Kill-Chain System has the capability to link disparate sensors and shooters and autonomously provide near-instantaneous targetable data. What these developing systems lack, however, is a scalable integrated 5G network that is coupled with edge computing at the forefront of the battlefield. Not only will this network allow for the immediate sharing of information of all units on the network, but it will also allow for immediate data processing between frontline fighters without requiring the data to be relocated back to an operations center for decision makers to republish it. With authority delegated down the chain of command, decentralized execution will become seamless.

5G and Edge Computing

Currently, the military relies heavily on disparate C2 systems such as Link-16, Blue Force Tracker, Riverjack Tracker, and Situational Awareness Data Link. Additionally, we have begun developing capabilities to bridge these systems using software like Sierra

Nevada's Tactical Radio Application Extension (TraX), which bridges information across domains and waveforms through its ability to understand and communicate across multiple military standard communications protocols.[6] While TraX helps systems "talk," it requires the software to be linked into each network to create a common operating picture and share data from assets on disparate networks. What is then required is a forward capability of putting everyone on the same network. TraX is just the beginning of what this technology is capable of.

5G is the next generation of cellular networks with speeds 100 times faster than 4G networks. It is a network capable of creating an Internet of Things (IoT) as it provides 99.999% reliability, end-to-end latency of 5ms, peak data rate of 10 Gb/s, mobility of 500km, energy efficient and can sustain a mobile data volume of 10 Tb/s/km².[7] An IoT itself is a collective network of connected devices or systems and the technology that facilitates communication between them and the cloud as well as between the devices themselves. With a 5G network, the DoD will be capable of managing and operating a massive IoT network providing unit autonomy, end user computing, autonomous systems, and faster latency speeds.

Through a 5G network, access to data from video, voice, sensors, targeting, reconnaissance, and even the sights on infantry weapons will be easy, and instantaneous for anyone who needs it.[8] A soldier at the front lines could be multi-broadcasting what their sight picture sees ahead of them to forces behind them, autonomously, and in real-time. To get to this capability, the DoD must find new ways to bring about data streaming edge computing solutions or build a network that provides more geographically distributed access. The goal is to allow the military to use edge computing without needing to reimagine their existing infrastructure. 5G with an edge computing system will bring the network connectivity up to speed with 5G and delivers near-instant communication.[9] Therefore, it is important that the DoD incorporates a 5G network that is supported by edge computing technology to create a new network capable of being scalable into its massive infrastructure.

This incredible network capability coupled with multi-access edge computing (MEC) provides endless technological possibilities to connect forces and instantaneously share time-sensitive data and information. MEC enables cloud servers to run closer to endpoints, reducing latency and speeding local processing (Figure 2 shows the difference between a traditional cloud structure and a MEC network).[10]

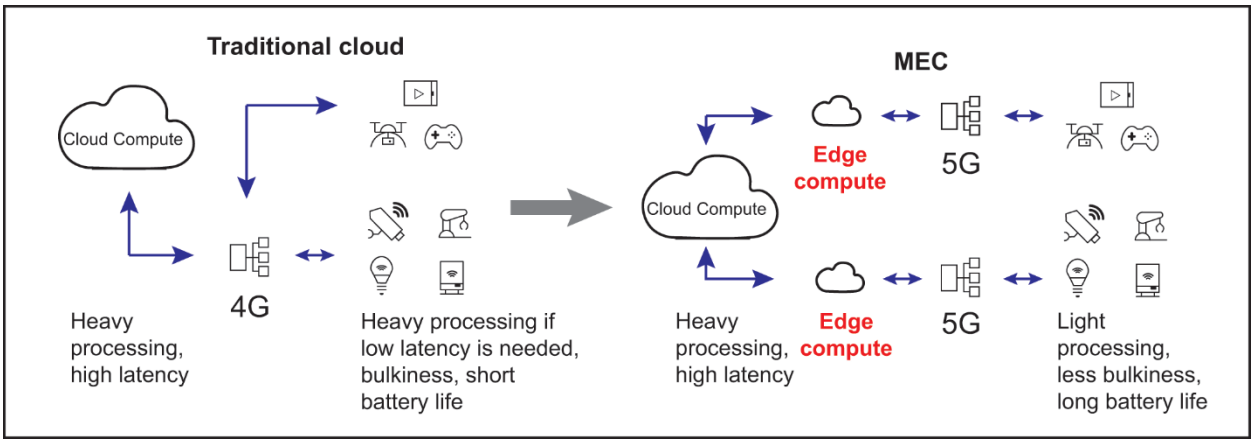

Figure 2: Traditional cloud network vs multi-access edge computing (MEC)

This provides the ability to support many more time sensitive applications and process data immediately with the end users at the forefront of the battlefield. The decentralized architecture of edge computing brings technological resources closer to where data is generated, reducing response time lags. Edge computing, when combined with 5G's large bandwidth, super-fast speeds, and significantly lower latency, is expected to enable the military to realize the full potential of innovations like artificial intelligence (AI), IoT, Massive Machine Type Communications (mMTC), Ultra-Reliable and Low Latency Communications (URLLC), immersive reality, and automation.[11]

Joint All-Domain Command and Control

Solving the conceptual problem of JADC2 has been on the forefront of military innovation. Nearly anything tied to developing or supporting the concept can get approved for funding and research. Everyone is looking at how individual pieces of technology can come together to support JADC2. While this is a large portion of developing the concept that is the future of military C2, we need to expand our innovation from just individual “stove piped” capabilities to rebuilding the network. The true significance of 5G can be seen in its effect on the future war network. A greater number of less costly, more connected, and more robust systems capable of operating in a rapidly changing combat scenario would support this network. Furthermore, 5G would combine fragmented networks into a single network, allowing soldiers to be more aware of their position and make better decisions. Positive effects will also be felt at the logistics and maintenance levels.[12] Once the network is developed, our individual technology and software can be reprogrammed to integrate within it.

To achieve this will be a massive step that will require the military to create a new network infrastructure. Partnerships with private networks such as Verizon and T-Mobile, could provide a foundation for a 5G network, while developing innovative systems that have the capability of pushing this network anywhere in the world. Mobile 5G towers can be established at forward bases while airborne C2 platforms such as the E-3 AWACS, P-3 Orion, RC-135 Rivet Joint, or new platforms, could provide airborne network extension or relay, similar to the already established Battlefield Airborne Communications Node (BACN). The extension capabilities are like that of Link-16 where users that are beyond line of sight with each other can still communicate through relays in between them.

Once a network is established, all forward sensors can be meshed and communicate with one another. The network will create an IoT through all connected users and advanced AI will prioritize and list massive incoming data from the front lines to decision makers in the rear. The process would be seamless and near simultaneous. Once connected, rear operation centers will have access to immense battlefield situational awareness, from the locations of full units to the video feed of a front line unmanned aerial vehicle (UAV), or even the sight picture of an M1 Abrams tank. Counterfire radar will automatically send targeting data to aircraft, and aircraft can publish targets they see that populate in ground units closest to them. Forward observers can mark targets while immediately pushing data to loitering munitions that are flying autonomously within their own airspace. Aircraft will be able to easily self-deconflict through proximity sensors to other aircraft. Sensors installed into artillery surface fires can create no fly areas within airspace as pilots will be able to see individual munitions flying through the air. 5G and edge computing can create a network of mMTC and URLLC.

No matter the branch, unit, or system, 5G will enable everything to “talk” to each other. Systems such as TraX will only be needed with incompatible 5G systems. TraX could then convert incoming radio frequencies from different platforms and translate them into a 5G capable message, just as it can take a Blue Force Tracker location and publish it on Link-16. This capability to link sensors seamlessly and autonomously to shooters will drastically reduce both the military targeting and decision-making process from minutes, down to mere seconds. The joint force commander will have complete situational awareness of all their assets and units. Navy destroyers will have the capability to communicate with Army forward observers, and Air Force units will be able to communicate with Marine artillery overseen by the same joint operations center. Forward reconnaissance aircraft will have the capability to locate deep targets and pass targeting data to enroute multiple launch rocket systems (MLRS). Once the MLRS arrive at an ACE airfield, they can immediately fire at the target. This is the near future capability of JADC2 on a 5G network.

Agile Combat Employment

In support of JADC2, the Air Force is experimenting with resilient C2 based around nomadic and mobile distributed C2 vehicles interconnected by 5G networks.[13] This mobile C2 capability was tested and proven capable in providing commanders with a solution to the JADC2 concept. A key requirement is to receive and transmit data from any military source, regardless of platform. The multi-domain battle management team (MBMT) developed and tested by the 1st Joint Special Operations Air Component (1st JSOAC) is a proven plug-and-play mobile C2 system that can integrate disparate networks and create an IoT that allows separate platforms to “see” and communicate with each other. Additionally, it creates a common operating picture for commanders that otherwise wouldn’t include every asset and have longer latency times that can affect decision makers. By integrating this mobile C2 system into a 5G network coupled with edge computing, the DoD would have a powerful JADC2 capability that can extend their reach anywhere on the battlefield while agile enough to execute within threat timelines and increase survivability through mobility and a small footprint.

The Air Force’s ACE strategy is the next hurdle in C2. ACE is a proactive and reactive operational scheme of maneuver executed within threat timelines to increase

survivability while generating combat power.[14] ACE is an operational concept that supports JADC2 but will require the military to fully reexamine our enabling systems for C2, logistics, and offensive and defensive capabilities. It shifts operations from centralized physical infrastructures and bases to a network of smaller, dispersed locations. Centralized command, distributed control, and decentralized execution provide the framework for the C2 of ACE.[15] This C2 framework is highly achievable through an integrated 5G network that could be established at each dispersed location.

Through a 5G network, commanders could produce tailorable force packages and maneuver or reroute them from one basing location to another while simultaneously tasking the required logistical support to the same location. For example, if a commander wants 4 bomber aircraft and 6 strike aircraft, the mission order is sent over the 5G network and is received by every unit's system, although only visible to those tasked. Within the network, those aircraft systems have a paired logistics package that is required wherever they go. Those packages are simultaneously ordered to the same location and 5G smart warehouse technology automates the maintenance and equipment support required. Transportation aircraft tied to the 5G network would constantly broadcast their location, cargo space, routes, and transit times. Simultaneously with the previous steps, the equipment and support needed are then allocated to the best suited mode of transportation to get to the forward basing location of the force package.

Impact on Logistics

A required capability development of ACE and potentially overlooked complex problem with the concept is the ability to develop, support, and sustain, scalable logistics packages for rapidly deployable force packages across dispersed locations. Dwight D. Eisenhower said, "You will not find it difficult to prove that battles, campaigns, and even wars have been won or lost primarily because of logistics." ACE will be a massive challenge and stress on the military's current logistics systems. Transformed and automated logistics will meet the demands of the ACE concept. Aside from prepositioning packages and leveraging commercial means, the military must develop tailorable logistics packages that are assigned to their supported force package. As dispersed sites grow in number across a wider operational area, sustainment plans and systems should also be capable of scaling sustainment operations to match.[16] Once a 5G network is established, the logistics to support a fast-moving force package over several locations will be nearly autonomous.

The first step in achieving this goal is establishing a 5G network within the military's sustainment warehouses. Although edge computing and 5G are not as widely used in logistics and supply chain as they could be, it will be a part of successful organization's future infrastructure as they provide greater computing power, performance, and reliability to support areas like warehouse automation and automated material handling. This automation includes tracking and tracing of assets to avoid data blind spots in the supply chain and the elimination of system downtime to avoid losses and failures.[17] Private usage has already shown that 5G in manufacturing has enabled advanced remote industrial robotics, remotely controlled factory operations with less energy consumption, and real-time digital plant management to identify capacity, track

production, and optimize operations.[18] This same manufacturing capability can be transferred into the complex world of military logistics.

The Marine Corps is already experimenting with 5G smart warehouse technologies for vehicle storage and maintenance, a capability that could be integrated into the ACE concept.[19] According to the DoD, the current 5G warehouse experimentation is focusing on efficiency improvements within warehouse operations, including receipt, storage, inventory control and tracking, issuance, and delivery.[20] Through the IoT and the capabilities of mMTC and URLLC, JADC2 could be supported through a fully autonomous logistics system. mMTC and URLLC frame the network for autonomous vehicles, smart cities, and industrial automation, all of which can be utilized in the DoD's logistics network.[21] Once commanders understand what type of force package is required to meet their objectives and where, the order is published to the network for those assets to move into position.

The movement of a specific force package would trigger a logistics and supply package in real-time through machine-to-machine communication based solely on the issued orders and planned flight path input into a lead pilot's avionics. The package then just needs approval at the centralized command level, but the complexities are complete, and the mission order is automatically received by logistic teams and supply systems upon approval. Within the network, those assets will have data identifiers that have a shared logistics requirement list. If items on the list are not already available at the gaining location, the logistics network kicks into action. If more items are required for sustainment, 5G warehouses are automatically notified, autonomous vehicles within them begin palletizing items, and the shipment process starts. Within minutes of orders being published, the required materials to support a new force package are being processed and enroute to the new location. If individual warehouses or units do not have the supply to support, messages are automatically sent within the system to adjacent units that can provide them. The possibilities of leveraging this technology within our logistics system are endless.

Future Weapon Capabilities

In addition to the advancement and capabilities of JADC2, 5G and edge computing will provide extreme advantages in the development and employment of future weapon technologies. 5G and edge computing will advance surveillance and situational awareness technologies. UAVs or drones can livestream photos and videos and use AI to create digital 3D maps in near real-time, enhancing situational awareness and allowing leaders to make more informed decisions. Commanders can use platforms that gather data from IoT sensors in the field and use AI to process the data into actionable insights to inform decision making.[22] All of which can be meshed with network enabled weapons to bring effects on the battlefield nearly immediately.

The Air Force's new B-21 long-range bomber is one of the first assets to operate within a "family of systems" that would accompany the aircraft during operations. Although little is exactly known about what that entails, it could include autonomous collaborative platforms such as drones that fly alongside and support the aircraft.[23] 5G sensors and edge computing would allow for the system to be fully autonomous and deconflict within itself and with outside obstacles. Another potential capability is to have unmanned

escort in defense of the aircraft with armed drones or loitering munitions. Loitering munitions are autonomous platforms that operate similar to drones and can fly for extended periods of time with the sole purpose of finding and striking an enemy target. They can be ground launched or onboard the supported aircraft and launched when needed. The Air Force is continuing to invest in this capability referred to as "Collaborative Combat Aircraft."[24]

In addition to collaborative combat aircraft, with mMTC and URLLC, the military can take advantage of a massive autonomous near-instantaneous strike capability through network enabled munitions. These long-range munitions will have extended loitering time and be able to autonomously fly to an airspace coordination area (ACA) near the forward edge of the battlefield while talking to other munitions within that ACA to remain deconflicted in transit. From this ACA, they will constantly be receiving targeting data from forward sensors, soldiers, drones, radar, etc. within the network. Network enabled weapons will allow air or surface launch through multiple types of platforms and go immediately to strike a target or to its designated loiter area for future engagements.

Planned within the division and brigade airspace, a Network Enabled Loitering Munition ACA will provide an immediate kinetic response to ground threats. Airborne assets carrying these munitions from adjacent area of operations could also send their weapons to bordering loiter areas for use of neighboring units. The 5G autonomy of the weapon will also automatically deconflict with other cross-boundary munitions, to include surface fires. Artillery shells will have small sensors installed that provide the shell's location in the network and allow for the simultaneous use of surface and airborne fire support with a greatly reduced risk of fratricide.

Once a forward target is identified by a sensor, the data is immediately published to the 5G network. A forward controller with an end user device, coupled with targeting software and TraX, will immediately see the list of targets populating on their map and immediately utilize an available loitering munition. Once a priority target is identified, the controller approves the use of a loitering munition to depart its ACA. A message that the munition is targeting the correct area is pushed to the controller, and the final order to engage is made with the push of a button. The target is destroyed, and the entire process happens within seconds of identifying the target (Figure 3 further details this process).

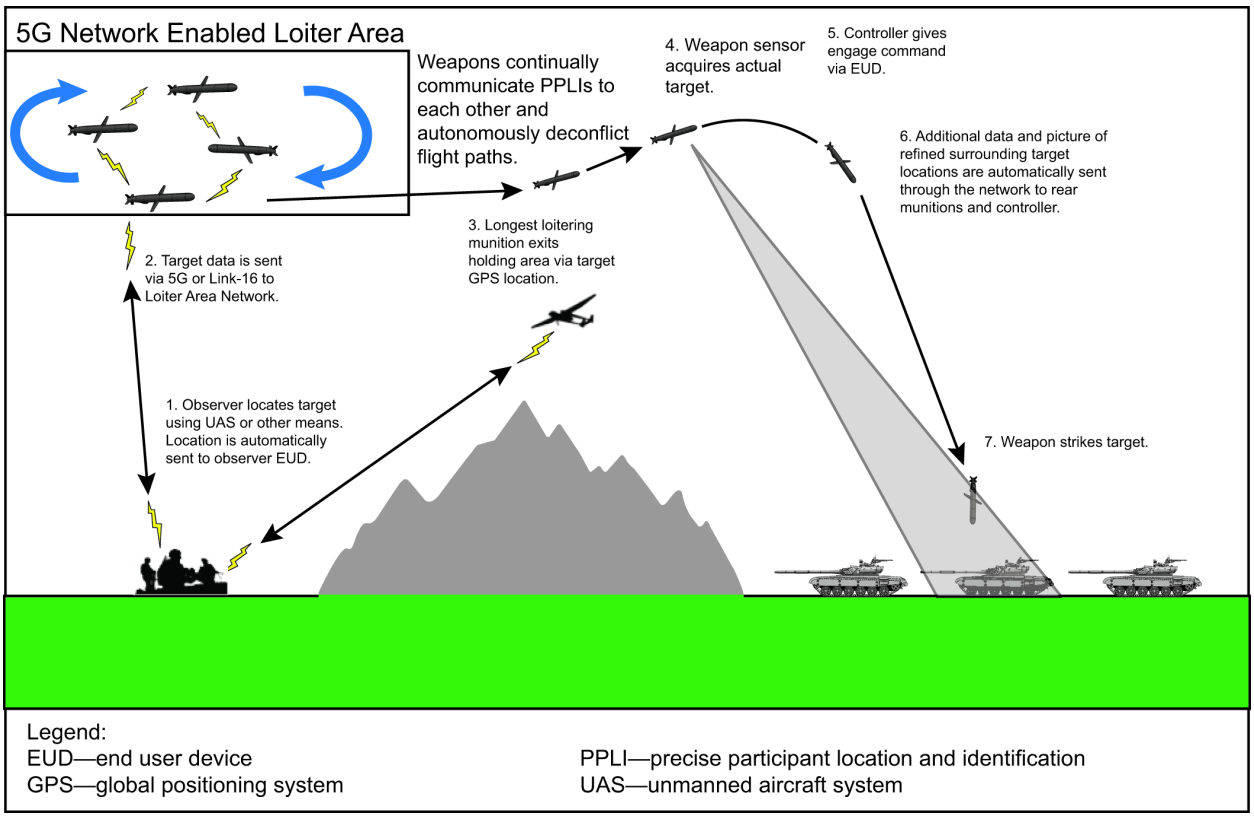

Figure 3: Implementation of 5G Network-Enabled Loitering Munitions Concept

Collaborative combat aircraft and network enabled loitering munitions are just the beginning of the endless possibilities of weapons that can be brought to the battlefield. The future battlefield network will become a living entity that is hard to jam through its vastness and thousands of interconnected platforms that provide network extension. The future of modern warfare will require decisions to be made within seconds instead of hours or minutes and to achieve such ability within C2, decentralized and nearly autonomous execution is required. The military's IoT will become its greatest advantage over its adversaries and create a joint fires capability that illustrates the path forward in bridging the connectivity gap between sensors and shooters on disparate datalink architectures. As the application of this nascent capability continues to refine and grow, it will begin to incorporate more sensors, and more weapon systems.

Conclusion

To advance the capabilities of JADC2, ACE, autonomous logistics, and future weapon capabilities, the military must begin developing the capability of deploying systems to create forward 5G networks. The military faces even stronger technological challenges because of the need to deploy 5G capabilities on the leading edge of the battlefield, where little, if any, 5G infrastructure exists, and where intentional radio frequency jamming or other kinds of interference from enemies is likely.[25] Partnership with private industry is vital to all aspects of implementing a 5G network into the DoD framework. Engaging with global industry leaders including 5G microelectronics manufacturers, telecommunications companies, and application developers will be integral to creating a new 5G network forward and in austere locations.[26] Once the capability to stand up a

5G network anywhere in the world is achieved, the possibilities the network provides will give immense strategic and operational advantage over any current adversary.

The DoD has adopted a partly parallel development process where some (or all) of the development activities at least partially overlap.[27] This means that while each branch of the military innovates towards the same goal, they are designing the process and systems while simultaneously developing the concept. This increases the difficulty of cross-coordination between the branches during innovation and has increased costs as multiple units spend resources in developing the same systems. To effectively implement a new concept such as JADC2 and integrate emerging technology, the DoD must first reorganize its developmental process and reduce research overlap and costs. Development at the unit or even branch level can create capability or organizational biases and shortfalls as they are not thinking enough about the "big picture." This new concept of development will be the first step towards grasping the full capability of 5G and edge computing.

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Editorial Note: As the joint and Service doctrine communities continue to refine and exercise JADC2, ALSSA publications such as Theater Air Ground System, Airspace Control, and Dynamic Targeting will incorporate the necessary revisions to tactics, techniques, and procedures to assist improving interoperability. Contact ALSSA or visit our website for additional information and updates on upcoming joint working groups.

End Notes.

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