Captain Joseph O'Brien, mission commander of Task Force New York City, greets medical providers joining USNS *Comfort*, which is working with Javits New York Medical Station as integrated system to relieve city's medical system, in support of U.S. Northern Command's Defense Support of Civil Authorities as response to COVID-19 pandemic, April 15, 2020 (U.S. Navy/Scott Bigley)

Decision Superiority Through Joint All-Domain Command and Control

By Terrence J. O'Shaughnessy

I have had the honor to lead both U.S. Northern Command (USNORTHCOM) and the binational North American Aerospace Defense Command (NORAD) for the past 2 years. During that time, the commands have undergone a critical transformation to ensure their collective ability to deter and defeat the very real threats posed by peer adversaries. In order to accomplish this no-fail homeland defense mission during a time of crisis, we must be able to perform a number of critical capabilities, which in their most distilled form are maintaining domain awareness, exercising command and control (C2) of assigned forces, and defeating adversary attacks. These capabilities are not new but rather have existed since each command's inception and have been key to providing a credible deterrent against our adversaries for many years.

While these critical capabilities for homeland defense may be enduring, the requirements needed to carry them out change over time. When I assumed

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command of USNORTHCOM and NORAD (NC&N), it was clear that we needed to rapidly improve our capabilities to fulfill the sacred mission of defending the homeland. Our adversaries had adapted, operating across new domains with faster and more advanced weaponry designed to circumvent our aging defenses. To counter these weapons and operate at the speed of relevance today, we must have awareness across all-domain C2 providing a fused threat picture across subsurface, maritime, land, air, near-space, space, and cyber activities, and defeat mechanisms capable of neutralizing adversary attacks against our critical infrastructure. The linchpin between these two capabilities is Joint All-Domain Command and Control (JADC2).

What is JADC2? Describing and ultimately producing JADC2 has proved elusive for the Department of Defense (DOD) because, in part, it is difficult to translate an aspirational concept into a shared vision and then into programming requirements. One approach has been to describe JADC2 by its desired attributes. In that sense, we talk about a redundant and resilient architecture to enable faster and more reliable communications, or the ability to link fused sensor and reporting data to the best shooter in ways that flatten unnecessary organizational hierarchies, gaining the leverage needed to deny an enemy the ability to hold us at risk. While these descriptions are certainly useful, JADC2 may be best described by its ultimate purpose: *decision superiority*.

JADC2 is C2 for the digital age—the architecture needed to produce faster and better decisions for our warfighters from the tactical edge to the strategic leader. What makes JADC2 different from previous C2 constructs is that it is built on a data-rich foundation that employs the power of machines to enhance decisionmaking. This new capability moves beyond the limitations of human capacities to produce machine-enabled insights that can identify anomalous events, anticipate what will happen next, and generate options with associated repercussions and risks.

To illustrate, a recent Amazon Web Service Next Gen Stats commercial shows at a basic level what this capability could look like (see figure 1). The commercial demonstrates artificial intelligence (AI) analyzing National Football League (NFL) plays. It identifies what AI-enabled insights could do for the decisionmaker, in this case an NFL quarterback. Using AI, a coach could assess whether the risks are worth the reward when looking at the probability of a completion for a 7-yard first down versus a lower probability but higher payoff for a 53-yard touchdown.

Beyond this simple illustration is an even more robust potential when we factor in machine learning (ML) based on previous patterns of behavior, incorporating historical analysis with the current situation to anticipate the future. A quarterback such as Tom Brady approaches the line of scrimmage with a brain processing two decades of NFL experiential learning. He knows the defensive coordinator whom he is facing and his own patterns for any number of circumstances, giving him a pre-snap edge when he evaluates the scheme. What machine-enabled insights could do, if the information could be transmitted to the quarterback in real time, is replicate that same capability for a rookie in his first game. A machine could actually process even more than the experienced quarterback if it understands what to look for. For example, a defensive coordinator may consistently show an overload to one side on third and long but drops out of the play post-snap, blitzing from the alternate side in order to pressure a hot throw toward an eagerly awaiting defensive back. Armed with that information regarding what is likely to happen, the rookie quarterback could come to a better assessment and take an action with a higher probability of success.

We seek these same data-driven advantages as military leaders. Current technology holds the potential not only to replicate the knowledge and wisdom of a commander with three decades of experience but also to improve on this knowledge by processing beyond the limits of a single mind. This applies both to the tactical edge, where machine processing of data could shorten our kill chains and help us identify threats that current systems struggle to detect, and to the operational/strategic levels, where machine-enabled insights could help us understand adversaries' patterns of behavior to anticipate what they may do next and generate various response options.

That all sounds promising. But how do we make that concept a reality? Over the course of the last year, we at NC&N have undertaken a campaign to dramatically improve our critical capabilities to meet homeland defense requirements in an increasingly threatening security environment. This campaign has focused on speed and innovation, incorporating both internal efforts to experiment with commercial industry as well as with the Air Force as the operational lead for their first two JADC2 demonstrations. Through these initiatives, we have been putting the "J" in JADC2, rapidly advancing from concept to reality.

Our pursuit of this aim yielded a four-part concept that articulates the essential subcomponents that, when combined, constitute our vision of JADC2. This concept helps to move beyond the descriptive elements of JADC2 to actually explicate a framework to produce the capability. First, at its foundation, JADC2 is a data problem. It must draw on authoritative data sources, both historical and current, that are material to an understanding of the relevant security environment conditions. Second, that data must be cloud-based, accessible up, down, and across command echelons at the appropriate classification levels. Third, the data must be layered and ultimately fused across domains and reporting streams to enable operationally useful visualizations in an all-domain common operating picture (COP). Fourth, and most important, JADC2 must incorporate machine-enabled insights into that COP. These insights simultaneously leverage predictive analytics, machine and deep learning, and AI to better understand the situation and generate data-driven analyses that offer our leaders decision superiority. This concept is the framework we are using to make JADC2 a reality and overcome today's most pressing C2 challenges.

Figure 1. AI Analyzing Football Play in Real Time

C2 Today

The challenge that we have across the joint and allied forces is to operate at the speed of relevancy to deter and defeat today's threats. These threats have advanced to the point that they stress our ability to react swiftly enough to counter them. The challenges posed by modern weaponry, in both speed and stealth, place a premium on the time it takes to go from sensing a threat to directing an action by the best available shooter to defeat it. We may be able to identify a threat, and we may have defeat mechanisms in place to intercept it, but if we cannot process the information in time to execute, we are at an extreme disadvantage.

C2 today relies on myriad data sources that are collected and refined at each command level without a common interface. That data is stored in stovepiped silos with either proprietary or bureaucratic limitations that impose accessibility challenges. The result is different operating pictures at each level of command and across the seams between the commands, which hinders collaboration and reduces clarity. Beyond that, the decisions produced from this legacy architecture are subject to the limitations of human processing—idiosyncratic experience, knowledge, and the peculiarities of momentary happenstance.

We recently wrestled with the impact of these challenges when NC&N supported the Nation's COVID-19 response. As the outbreak spread, we received direction to lead DOD operations in the United States. Within 48 hours, we stood up both joint maritime and land component commands and established a flexible C2 architecture to support the dynamic employment of capabilities across the country, including the forward deployment of medical personnel into the heart of the outbreak in New York City. Using legacy C2 systems, we immediately found ourselves struggling to maintain situational awareness in order to inform the Nation's senior leaders as well as my own decisionmaking about what needed to be where and when to best accomplish our mission. In these early stages of the crisis, we used the traditional manual reporting through a hierarchical chain to aggregate data in Excel spreadsheets and PowerPoint slides, taking hundreds of hours to ultimately produce reports that were too stale to be useful.

Applying the JADC2 Concept

We were able to overcome the C2 challenges we faced at the outset of the COVID-19 response because of the unique opportunity it presented. There was a shared sense of urgency as part of the whole-of-nation effort, especially with commercial industry partners that were eager to assist. With them we were able to accelerate the progress on JADC2 development by applying the same four-part concept we had developed to address the homeland defense challenges posed by peer threats.

Solving the problem started with finding authoritative data, which meant moving data entry in most cases to the edge and cutting out redundant layers. For example, we accomplished this mission by working with two technology companies to deploy smart devices to forward-deployed units at places such as the Javits Center in New York City, where medical units could provide real-time status updates through custom-built apps and commercial online collaboration tools. This ability enabled us to track different statuses such as location, health, and personal protective equipment for these personnel. Moreover, the mobile devices allowed me to virtually interact with the medical units to get the frontline pulse when I could not physically visit.

The second key step was to move that data to the cloud. We worked with the Joint Artificial Intelligence Center to host our data and enable industry entities to access it to produce operationally useful visualizations in the form of COPs. To accomplish this undertaking, we worked with two software companies to develop displays for not only medical statuses across the country but logistics and deployment information as well, providing real-time situational awareness across subordinate commands.

The pivotal part of our JADC2 concept, incorporating machine-enabled insights into the COP, proved most useful. We coordinated with an innovation laboratory and other tech firms to leverage predictive analytics to inform decisions. For example, we were able to bring in a number of data sources from across government and the private sector to develop a model that anticipated 2 weeks out where COVID-19 spikes were going to occur and where that outbreak would coincide with medical capacity shortfalls. Based on that model, I received a briefing on April 14 that identified a location of concern just north of New York City. Based on an exodus of people from Manhattan to the Connecticut suburbs, the model predicted an outbreak around Stamford, and we dispatched a surge of expeditionary medical capabilities in anticipation of the need for increased capacity. The model proved prescient. There were 412 new cases on April 19, and by April 22 that number had ballooned to 2,109.[1] Fortunately, we were able to get capabilities in place in time by drawing on the power of big data and predictive analytics to inform an operational decision. This success was largely due to a concerted and iterative effort to pursue JADC2 capabilities for homeland defense in the year leading up to the COVID-19 pandemic.

Delivering JADC2

Our COVID-19 response provided the opportunity for us to validate, leverage, and accelerate JADC2 initiatives that had begun the previous year as part of our homeland defense transformation. We had been well aware of our capability challenges at NC&N for quite some time and had conducted a series of studies over the years to understand our gaps and shortfalls as well as possible solutions to address advancing threats. In fact, there were so many different analytic efforts under way that we conducted a study of the studies just to understand how they all fit together. We learned that the myriad studies had reached a point of diminishing returns and that we needed simply to start solving the problem. We acknowledged that we would not get it exactly right out of the gate, but the newly adopted agile development approach allowed us to make iterative and rapid progress.

Based on that predilection for action, our JADC2 concept development took the form of praxis: taking the theory or idea behind JADC2—namely producing decision superiority—and actively attempting to build it out in the field. Knowing that time was not on our side, we employed an agile development model with technologically innovative commercial entities to break out of the standard capability procurement process. We thought big, started small, failed fast, and reinforced success. This approach included prototyping, experiments, and demonstrations over the last year aimed at producing the critical requirements needed to modernize our defenses.

The campaign started with a focus on shoring up potential vulnerabilities in air domain awareness to improve detection and responsiveness via a prototype called Pathfinder. Pathfinder harnessed the power of competition among industry innovators to quickly generate leap-ahead technology. Access to commercial industry was made possible through collaboration with the Defense Innovation Unit (DIU), bringing Silicon Valley talent to bear on our problem set. What DIU helped us create is a cloud-based data ecosystem that draws on disparate air domain feeds (for example, Federal Aviation Administration radars), pulling them into the cloud where data processors can run algorithms to identify tracks that legacy systems were unable to collect. This capability improves not only our sensing grid for identifying traditional offensive platforms such as aircraft but also the detection of launched weapons and unmanned aerial systems (UAS).

Pathfinder was only the beginning. We spearheaded additional experiments with commercial industry to improve detection against cruise missiles and UAS. We worked with companies that developed ML- and AI-enabled detect capabilities positioned at the tactical edge to identify a threat much earlier than previously possible, eliminating layers of reporting. In addition, these companies provided an advanced virtual user interface for the COP where the machine presented the operator with tasking options for various defeat mechanisms to intercept the missiles—in that case, a virtual engagement by an F-22 Raptor.

Based on the success of these early prototypes and experiments, the Air Force requested that we serve as the operational lead for the Advanced Battle Management System "onramp" number one. The Air Force and my team were focused on creating true JADC2 and had similarly adopted a DevOps approach in that pursuit.[2] Knowing the standard model to develop the needed capabilities would take too long, we were not afraid to try a different course. We cast a wide net, explaining our homeland defense needs to companies and agencies that could potentially be part of the solution. Rather than ask for specific capabilities, we described our challenges. When we found those with similar mindsets, whether in industry or across the Intelligence Community, we quickly merged our efforts to work toward mutually beneficial aims.

Because our team served as the vanguard for the onramp development, we were able to incorporate industry entities and government partners in prototyping and testing to quickly produce the results needed to illustrate what was within the realm of the possible. The first time we were able to successfully apply the JADC2 model with a wide range of joint

Connecticut National Guard Soldiers and Airmen set up 200 beds at Stamford Hospital and construct Alaskan Small Shelter System tents for separate triage area in response to COVID-19 pandemic (U.S. Air National Guard/Steven Tucker)

force participants happened at Eglin Air Force Base, Florida, in December 2019. The onramp scenario allowed us to collect authoritative data processed at the edge, pull those feeds into a data cloud, apply machine-enabled insights to present tactical-level employment options, and finally display that information in a multidomain COP for the decisionmaker.

Through this pragmatic and iterative approach using experiments and demonstrations, we identified our process for building JADC2. A proven four-step concept emerged as a way to organize action and explain how one process leads to the next with the goal of achieving decision superiority: data—cloud—machines—COP.

Building JADC2

Authoritative Data. The first key to operating at the speed of relevancy is finding the authoritative data sources, prioritizing them, and removing redundant input layers. The effect of this operation is the flattening of unnecessary layers within the C2 construct, thus removing potential for erroneous reporting and reducing hours of processing. Depending on the data in question, the authoritative source may be a sensor such as a radar feed, a traditional C2 node at a headquarters, or an open-source report coming through social media. When we think of our defenses for the homeland, we must look to identify and fuse feeds with all pertinent reporting streams to create a layered sensing grid from subsurface to on-orbit sensors that can support all-domain awareness from incoming threats.

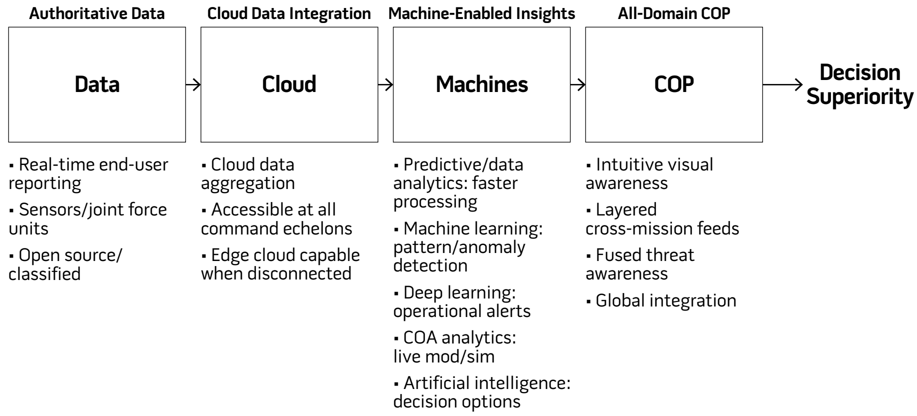
Cloud Data Integration. That data must then be integrated into a cloud-based architecture that is openly accessible both vertically and horizontally across the echelons of commands and organizations that require its use. Importantly, that architecture must also be able to accommodate multiple classification levels, granting access based on the identity of the user to break down the compartmentalized silos that exist today among organizations and partner nations that inhibit a unified and coordinated response.

All-Domain Common Operating Picture. Next, that data must be visually represented in operationally useful ways in the form of an all-domain COP. The feeds that are integrated into the visualizations must not only be layered but also fused to correlate tracks and reports to reduce uncertainty and increase assessment speed. Ideally, the COP would have multifunctionality, with the ability to toggle among a variety of customizable visualizations within one framework rather than relying on multiple COPs that necessitate greater manning and human-to-human processing. Instead of a static output, user-defined visualization permits operators to select the data sources that they are concerned with as well as to tailor the manner of display to best enable understanding and decisionmaking. In the digital age, data-rich machine-based analytics demand sophisticated user-friendly visualization to optimize decisionmaking. Our current prototype COP operates in just this way; it is data- rather than platform-based, applying technology to meet the emerging needs of a commander. The production of a COP that provides a rich understanding of the current situation and how it came about is the termination point of most C2-enhancement efforts before now. While those aims certainly advance beyond where many commands are today, it does not enable decision superiority on par with what we need to contend with the threats of today as well as tomorrow. To ensure superiority, we must employ tools that allow us to anticipate what will likely happen in the future and assess our options. This is where machines are required. Advanced processing power, ML, and AI can take C2 to another level (see figure 2).

Machine-Enabled Insights. Machines are *the* key component of JADC2. They offer the potential to move beyond our human limitations and create a better understanding not only of the current situation but also of the future—and how our potential actions are likely to play out. We have long had goals to produce this type of technological foresight capability. The difference is the capabilities to produce this insight are no longer the substance of science fiction. They are readily employed across virtually every aspect of our lives, from car navigation to tailoring online shopping options. The power of machines needs to be unleashed not only to enhance our way of life but also to protect our lives themselves.

To accomplish this goal we must call on machines to perform a variety of functions in support of JADC2. First, employing big data and predictive analytics could allow us to process large amounts of information that would otherwise take thousands of human hours. This ability speeds up processing and creates a deeper appreciation of the situation at hand. Today it takes legions of analysts poring over reams of intelligence data to establish connections between their observations. If the subject of their inquiry could be translated into a task for a machine to process, exponentially more data could be analyzed and many more meaningful connections might be identified, freeing up analysts to focus on tasks that only a person is able to tackle.

Figure 2. USNORTHCOMJADC2 Concept



Next, we could look to ML to incorporate historical data and identify significant patterns and anomalies that might indicate an adversary's intent. For instance, we might learn over time that certain indicators are correlated with military maneuvers beyond those that we might typically associate. Commodity prices near a base could fluctuate. Ordering for replacement parts for military equipment could precede deployments in predictable patterns. All these could serve as queues to help us better anticipate when something anomalous or consistent with a concerning activity is occurring.

Beyond that, machines could link those ML-enabled detections together to produce deep learning. Deep learning would help us establish a broader pattern of life for the adversary that could generate operational alerts when there is a confluence of concerning indicators. Those processes incorporate real-time and historical feeds to create an understanding of what has happened, is happening, and is likely to happen. By allowing machine and deep learning to identify whole new subsets of observable behaviors or conditions, we potentially move our decision space to the left of launch, giving us greater flexibility and more time to prepare a response.

We could also leverage machines to incorporate the hypothetical. By layering modeling and simulations for both enemy and friendly actions into the same interface, we could allow the machine to run multiple scenarios against various contingency force postures. Employing AI against these simulations affords the machine the opportunity to iteratively learn and develop options for decision. The options generated through this data-rich process place the decisionmaker in an advantageous position by providing recommendations, implications, and follow-on effects along with concomitant risks.

This is made possible by increasing both the breadth and depth of the data analysis. We are not just talking about having a computer generate some prescripted responses based on a few indicators. Increasing the breadth of the data pool provides the opportunity to expose novel correlations that we could link to adversary behavior. The depth of the analysis afforded by advanced analytics allows for a much richer understanding of a situation over time by incorporating orders of magnitude more data than we currently use. For example, Monte Carlo analysis could provide much deeper insight into a wide range of possible future outcomes and the risks associated with them.[3] This data-driven approach provides highly granular understanding to move decisionmaking from reactive to anticipatory and proactive. Decisionmakers could have more sophisticated insight into complex problems and make decisions with much clearer understanding of the ramifications on future operations.

General Terrence O'Shaughnessy addresses National Defense University's combined colleges as part of University's President's Lecture Series, at Fort Lesley J. McNair, Washington, DC, April 21, 2019 (NDU/Katie Persons Lewis)

To be clear, humans will still make the decision, but they will do so from a much more informed perspective based on the input from machines. Today, when a crisis situation arises, I rely on a colonel with over 20 years of experience and his or her team on the watch floor of our USNORTHCOM and NORAD Command Center to help me make decisions. This team rapidly processes the information that is projected onto a bank of screens from a vast number of reporting feeds. These individuals, each responsible for a different aspect of the complete picture, correlate and make sense of that data as quickly as possible using only their innate processing power, doing an admirable job given their current capability suites. However, the technology exists today for us to do much better. Only by fully harnessing the potential of machines will we ultimately achieve JADC2's goal of producing decision superiority.

Today's security environment requires military leaders to be armed not just with current information, but also with operational insights that will enable better and faster decisions. Keenly aware of this immediate need, we at USNORTHCOM and NORAD have led the charge working with both DOD and commercial industry partners through an iterative approach to build that capability. Our efforts to jump from the PowerPoint slide to the field yielded a four-part concept that disambiguates JADC2 and accomplishes two important things: first, it provides a framework that makes it easier to orchestrate efforts to create and enhance JADC2 for our formations; second, it helps articulate how JADC2 differs from previous C2 advancement initiatives—namely the inclusion of machine-enabled insights to identify anomalous events, predict what is likely to happen next, and generate options that overcome human limitations. This is a significant progression from where we were on this effort just a few years ago, but we cannot rest. We must continue this unrelenting pursuit for JADC2, as it is the core capability that the joint force needs to fight and win in the digital age. Because of the work we have done with innovative teams in an agile development model, we now have a better understanding of what we need JADC2 to do and how to make it real. Decision superiority, enabled by JADC2, is the competitive advantage we need against peer adversaries. **JFQ**

Notes

[1] Patrick Tucker, "How the Pandemic Is Helping the Military Prep for World War III," *Defense One*, May 26, 2020, available at <www.defenseone.com/technology/2020/05/how-pandemic-helping-military-prep-world-war-iii/165656/>.

[2] DevOps refers to an approach that combines software development with operations to increase the rate of innovation.

[3] Monte Carlo analysis is a method that uses statistical evaluation of randomized data sets to better understand things such as probability distribution.