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ENVISIONING A NEW COMMAND & CONTROL (C2) ARCHITECTURE FOR ALL-DOMAIN OPERATIONS

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The Challenges of Today's Operational Environment

The 2018 National Defense Strategy shifted the Department of Defense's (DoD's) strategic focus to preparing for a future high-end conflict against peer adversaries where the Joint Force will need to operate at long ranges, close kill chains rapidly, and address adversary anti-access and area-denial (A2/AD) capabilities. That will require the United States and its mission partners to rapidly plan and execute operations by employing convergent capabilities from across all warfighting domains, agnostic of the force provider, and by operationalizing the non-physical battlespace.

Achieving the mass, scale, and simultaneity needed for successful all-domain operations demands an entirely new approach to Joint Command and Control (C2) and battle management that provides commanders the ability to rapidly recognize, understand, decide, and execute operations. Today, planning, synchronization, and execution of combined operations at the speed required is difficult if not impossible as legacy C2 systems are impeded by multiple barriers including those between warfighting domains, across echelons and classification levels, between the military services themselves, and with our allies and partners.

A Joint C2 Vision for the Future

Providing commanders with superior sense and decision-making capability in future conflicts will require a new battle command architecture that enables contextual access and exploitation of all available data to establish a shared, clear understanding of the situation, assigned mission, available resources, and force employment options, based on mission or warfighting functional need. What is needed is a mission-driven, all-domain situational awareness capability to provide the foundation for improving the speed, scale, and effectiveness of decision-making.

ACHIEVING THE MASS, SCALE, AND SIMULTANEITY NEEDED FOR SUCCESSFUL ALL-DOMAIN OPERATIONS DEMANDS AN ENTIRELY NEW APPROACH TO JOINT (C2) AND BATTLE MANAGEMENT THAT PROVIDES COMMANDERS THE ABILITY TO RAPIDLY RECOGNIZE, UNDERSTAND, DECIDE, AND EXECUTE OPERATIONS.

Integrating technologies such as artificial intelligence, machine learning, and real-time modeling and simulation of asset options will better enable commanders to optimize available resources. Moreover, to provide resilience in the face of adversary attacks, the new battle command architecture must be designed for decentralized C2 that can enable widely distributed operations across a large battlespace. And to overcome the fragility of single and cross-domain kill chains, the architecture must employ an all-domain kill web using diverse communications paths and machine-to-machine transmission of data.

Yet, several barriers must be overcome to realize this vision for advanced battle management. For sense-making, the DoD and Intelligence Community (IC) are currently unable to easily orchestrate intelligence collection and combine and analyze disparate data sets, including non-traditional data. The result is an inability to share the situational awareness and battlespace understanding required in today's dynamic environment. Furthermore, employable decision-making assets and combat systems are divided by military Service or warfighting domain. That means there is a limited ability to understand the full range of capabilities available to achieve the commander's intent, desired effects on targets, and ultimately mission objectives.

Establishing a Next-Generation C2 Architecture

A particularly compelling challenge facing the Joint Force is meeting the rapid timelines required for finding, fixing, and engaging the relocatable systems that peer adversaries increasingly rely upon to create standoff via robust A2/AD defensive networks. Addressing this challenge will require employing new and innovative technologies in domain- and service-agnostic ways to dramatically accelerate all-domain kill chain functions.

For example, human-machine teaming can be used for better option selection and to accelerate decision-making. This will create the ability to leverage context-aware displays and tailorable mission dashboards and analytics, allowing commanders to visualize and understand the current and projected situation and associated strengths, weaknesses, gaps, and opportunities, thus improving the speed of battlespace recognition, planning, decision, and action. The idea is to initiate improved operational workflow and kill chain execution, along with associated data brokering, and asset orchestration in time, space, and purpose. Furthermore, collaborative battlespace operations as well as deconfliction can be aided via dynamic battlespace management processes that leverage the information and knowledge produced by contextual awareness.

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Today's C2 structure must be significantly adapted to realize all-domain convergence at speed and scale and therefore enable the fast sense and decision-making required in a dynamic, complex fight at the operational or theater level of war. To fully achieve this vision, the next generation Joint C2 architecture must shift from single service and domain-centric operations centers to Joint All-domain Operations Centers (ADOCs) that are mission/function-oriented and distributed globally across operating areas. These must also be connected to service-provided multi-domain force packages and battle management teams. ADOCs and battle management teams exploit shared, contextual all domain, all services, all partner situational understanding that replaces fragmented situational awareness resulting from isolated domain or service architectures.

In this proposed structure, collaboration and dynamic tasking of integrated all-domain assets replace staff-intensive coordination, synchronization, and deconfliction processes associated with deliberate single domain planning and traditional C2 structures. The human-machine team replaces manually intensive military decision-making processes within the ADOCs for strategic and operational-level planning. Integrated kinetic and non-kinetic effects planning and employment and operationalizing the non-physical battlespace (the electromagnetic spectrum and information environments) improve force integration and synergy.

Decentralized C2 employing conditions-based and distributed authorities and dynamic network and data access planning replaces centralized C2 structures and fixed single domain focused operations centers. And an agile and resilient global network connects the ADOCs, multi-domain forces, and battle management teams replacing a complex set of disparate Joint and service networks streamlining information exchange and machine-to-machine communications.

Operational Vignettes

If the DoD successfully develops and deploys Joint C2 capabilities for all-domain operations according to the ideas outlined above, what might a future conflict look like? The following fictional vignettes aim to help answer that question.

The scenarios presented each pose considerable operational challenges for the Joint Force. The adversary has advantages in terms of geography, initiative, and force generation. Given these challenges, a likely adversary course of action would be to move quickly and aggressively to seize territory, then use A2/AD capabilities to hold the U.S. and its mission partners at bay to consolidate gains and challenge a unified response. The adversary objective is to achieve a fait accompli for its military actions and return to a state of global competition.

A U.S. and allied/coalition response would undoubtedly seek to slow the adversary advance, attrit their forces, and disrupt their offensive in order to prevent establishment of the sought-after fait accompli position. Given the limited assets immediately available to the theater commander, achieving these goals would require rapidly and simultaneously engaging adversary air and maneuver forces from all domains prior to establishing domain superiority. In sum, one of the primary operational challenges will be to rapidly instantiate precision fires against large numbers of mobile platforms and relocatable targets from multiple domains in a highly contested environment. By destroying these targets, the U.S. and its partners can dis-integrate the adversary's A2/AD network to eliminate the standoff threat on friendly forces.

Notional Vignette #1

Full-scale hostilities have commenced. With little to no warning and before U.S and partner forces could fully organize and mobilize, adversary conventional military units launched a ground invasion against a U.S. ally. While U.S. and mission partner intelligence provided some indications of adversary intentions, multiple political and military factors delayed the initial response. A focused campaign to deny and degrade U.S. intelligence collection, mask intentions, and divert attention to other global hot spots was largely successful. While the U.S. was able to rapidly deploy global response forces into the theater prior to the invasion, U.S. Army heavy forces, specifically Armored Brigade Combat Teams, have not yet arrived.

Initial adversary operations focused on degrading U.S. and allied/coalition C2 networks to dominate the information environment. The enemy's cyber offensive targeted space assets, with uplink jamming and cyber penetration of key tracking, telemetry, and control links. Adversary cyber forces were able to inject false data directly into the Combined/Joint Force's common operating picture. High-fidelity air, land, and undersea decoys, along with military deception, information warfare, camouflage, and carefully orchestrated cyber and electronic warfare (EW) attacks, combined in attempts to spoof and manipulate U.S. commanders. As widespread network blackouts descended over the allied country and its neighbors, and under cover of an unrelenting electromagnetic barrage across the region, adversary ground, air, and naval forces advanced. Even as U.S. and partner stand-off precision strikes targeted logistics and staging areas, local allied defenses and U.S expeditionary forces, consisting primarily of airborne infantry, were swept aside or melted away into forested terrain in the face of the enemy's massed artillery fire. Adversary land forces rapidly moved to occupy territory and key positions.

The Combined/Joint Force Commander charged with defeating the adversary offensive has aligned forces along functional lines, rather than by domain components or service affiliation. The commander convenes a virtual meeting with subordinate commanders participating from their distributed operations centers across the region and in the continental United States, including leaders responsible for Intelligence, Surveillance, and Reconnaissance (ISR), Space Control, Fires, Information, Logistics, and other warfighting functions and priority missions. Each commander is delegated authority to command and control forces within their functional lane, regardless of service. The Fires Commander, a U.S. Army two-star general, for example, holds tasking authority for both allocated long-range precision ground fires and tactical airborne strike platforms. Likewise, the ISR Commander controls tasking for space, ground, and naval sensors. While this type of organizational system caused difficulties when first fielded, extensive experimentation and joint exercises have ironed out many of the kinks. This will be the first test in actual combat of a new Joint All-domain C2 (JADC2) architecture.

RECENT UPGRADES TO C2, NETWORK, AND DATA SYSTEMS PROVIDE RESILIENCY IN THE FACE OF ADVERSARY ATTACKS ALLOWING THE COMMANDER TO DISAGGREGATE AND AGGREGATE FORCES AS THE SITUATION DICTATES AND EXERCISE DECENTRALIZED C2 OF THESE FORCES USING CONDITIONS-BASED AUTHORITIES ACROSS ECHELONS.

Recent upgrades to C2, network, and data systems provide resiliency in the face of adversary attacks allowing the commander to disaggregate and aggregate forces as the situation dictates and exercise decentralized C2 of these forces using conditions-based authorities across echelons. Communications path and link diversity and redundancy help the network recover and provide connectivity to a digital web of ISR options for the commander enabling the development of contextual awareness, visualization, and understanding of the all-domain battlespace.

At the initial crisis meeting, the ISR Commander is armed with information from a theater cooperative sensor grid that can consolidate, fuse, and share data to and from widely distributed operational elements. Gone are the days of fragmented situational awareness, isolated by different services and warfighting domains and only integrated manually with resulting errors and critical gaps. Instead, machine-enabled, context-based situational understanding is shared widely and rapidly.

The gathered commanders quickly agree that one of the highest priorities for the sensor grid will be to locate and track high-threat mobile assets, particularly any short- and medium-range ballistic missile systems and long- and medium-range mobile air defense systems. The ISR Commander communicates this "Commander's Intent" to subordinate leaders, who immediately incorporate it into the algorithms helping them task and prioritize intelligence assets. These algorithms feed a machine-driven battle management network capable of assembling and orchestrating a detailed ISR collection plan. This plan accounts for and adapts to real-time battlefield conditions and threats; the availability, strengths, limitations, and tradeoffs between the systems it can task; and predictions about threat behaviors based on geography and past observed actions.

As a result of the new priorities, the battle management system starts building a revised plan. It first produces a long list of high-priority collection requirements. These include previously identified march routes for high-threat systems along with potential choke points. As quickly as they are generated, targeting tasks are passed machine to machine to decentralized tactical-level C2 nodes receiving constant updates, and the automatic process of "task brokering" begins. The brokering process rapidly identifies surviving

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ISR assets able to look deep into enemy airspace and those limited to sensing near the front lines, separating out those degraded by relentless adversary cyber and EW barrages.

Meanwhile, a U.S. Cyber Mission Force successfully hacks into a critical adversary C2 node. Algorithms rapidly sift through mountains of data to identify potential air defense system operating locations. Each location becomes a new imaging task added to the ISR queue and parceled out to space-based, ground, and airborne assets through the brokering process. As these assets are queried, each provides options for the commanders, again machine to machine, including best estimates and projected uncertainty of potential effectiveness in achieving specific ISR taskings.

It is a far cry from the legacy tasking system with its 24-hour planning cycle and only limited assets available for dynamic tasking. The process then matches platforms to taskings based on multiple factors, including this effectiveness estimate, predicted time to complete tasking, and the "'opportunity cost" of re-tasking an asset away from other collection requirements. An ISR operations officer in the Combined/Joint Force ADOC reviews the recommended plan, which includes estimated success rates and likely costs in terms of friendly casualties. The preferred plan is presented along with some additional machine generated alternatives in an intuitive decision support display. After making several small changes, the officer approves the newly revised collection plan, and new instructions are sent – again, machine to machine – to ISR assets in the field for execution.

Given the highly contested environment, few airborne or ground-based platforms are available to gather the intelligence needed to quickly locate these high-priority targets. Instead, the remaining operational overhead imagery satellites are given the job of examining likely threat positions. As each is tasked, the Joint Tactical Grid, providing the Combined/Joint Force with resilient communications, notifies the Space Control commander and duty officers in the ADOC. Through the network, the Space Control section is presented a dynamically updated list of space assets, their status, and their planned collection taskings. The brokering algorithm then uses this information to continuously allocate and re-allocate scarce resources for protecting both government and commercial systems. Within seconds of being alerted of the new tasking, the network recommends re-rolling a Cyber Protection Team (CPT) to provide point defense for the ground segment of an overhead satellite. The Space Control duty officer concurs, and before she can verbalize her actions, both the CPT and the ISR teams are notified of the change.

As it completes one of its pre-planned taskings, a space-based infrared sensor detects a flash indicating a possible medium-range ballistic missile launch. Missile defense assets are immediately notified machine to machine via the ISR broker. Simultaneously, an imaging task is instantly generated to better geolocate the launcher, prompting another ISR assignment re-plan. An airborne imaging sensor near the target scores high on the mission performance assessment. In minutes, it images the launcher location, and an onboard machine vision algorithm quickly parses through the sensor's data stream confirming with high confidence the enemy system's signature. The raw data and the machine assessment are passed to a human analyst for verification. Because high-confidence data on missile locations is such a priority, the decision support display interrupts the analyst's workflow and directs his attention to this task. He quickly confirms target identification, and the target coordinates are automatically passed machine to machine to the Fires C2 element, along with amplifying information such as how long the coordinates are projected to remain valid.

Within the Fires element of the Combined/Joint Force ADOC, time-critical tasks such as this one flow in from across the battlespace. Ground units calling for counter-battery fires against adversary rocket and artillery units, for example, add to the growing list of actionable targets. As with ISR, a brokering algorithm uses system performance estimates, target types, and current battlefield conditions, along with other inputs to optimize target engagement. Fire and strike missions are sent to platforms and units after a Fires officer has reviewed, modified, and approved the plan. Given the strategic importance and fleeting nature of the target, an Army hypersonic missile battery is tasked and immediately begins launch preparations. Navy Tomahawk land attack cruise missiles are tasked to strike deeper fixed targets, while targets closer to the edge of the adversary's

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integrated air defense bubble are passed to F-35s with precision guided munitions.

As strike missions are completed, battle damage assessment tasks are automatically generated and sent machine to machine to the ISR element to be included in the list of imaging tasks. This process of optimizing resources, effects, and time across domains to simultaneously complete numerous parallel kill chains against fleeting targets is replicated across the entire battlespace. At times, electronic attack and the inevitable fog and friction of warfare disconnect forces from the brokering agents. In these cases, the forces continue with their pre-planned assignments, executing based on mission type orders. In some circumstances, "local markets" appear where ISR and Fires assets can communicate with one another but not with any higher control agency.

As the opening hours of the conflict end, the commander reflects on the decisions made during the day. Impressed with the team's ability to sense, decide, and act faster than any force in history, the commander is thankful for the agility, resiliency, and speed provided by JADC2 over traditional C2 constructs of the past. The ability to optimize weapons target pairing by assigning assets to a target based on availability and probability of success, agnostic of owning service, formation, or domain, is a game changer. The commander was able to access and exploit all available data based on mission need, and apply analytics to help visualize, assess, and understand the evolving situation. Leveraging technology, the commander optimized the overall C2 cycle reducing the number of human-to-human interactions required in past operations while improving the efficiency and speed of decisions.

Notional Vignette #2

To maintain freedom of action in a contested ocean, the geographic U.S. combatant command begins operations to roll back adversary anti-air, anti-land, and anti-ship systems deployed in the region. The initial focus is on a contested island chain and adversary naval vessels operating in that region. For some time, the combatant command has undertaken extensive efforts to understand, track, and map adversary activities and patterns of life in the region, particularly of mobile high-threat systems. Airborne Ground Movement Target Indicator sensors performed long-endurance missions observing traffic on and near the islands to map activity and roads used, understand deception traffic, and assess the ability to monitor the region from sufficient standoff. Space assets were employed with similar goals, including heavy use of non-traditional space systems such as commercial constellations as well as more traditional space capabilities to establish patterns of life. Over time, understanding has grown of how different modalities can be used to cue each other, of pre-planning adversary operating locations, and of normal adversary patterns of life. This information is then used to create attribute layers available to command and control centers at the operational level and to tactical intelligence operating nodes such as the Distributed Common Ground System.

As the conflict phase opens, the combatant commander prioritizes finding both high-end air-defense systems that can threaten U.S. aircraft and medium-range ballistic missiles that have the range and precision to strike U.S. land and sea bases. To that end, a Combined/Joint Force is established, which stands up an ADOC, well outside the range rings of any threat missile systems. The ADOC includes individual operational-level C2 elements focused on Surface ISR, Surface Strike, and Integrated Air and Missile Defense missions. Each of the operational C2 elements is given tasking authority over the assets specific to its focus area, with high-altitude, air breathing systems, along with commercial and other space-based ISR capabilities under the control of the Surface ISR element, as well as Navy P-8 maritime patrol aircraft distributed between Surface ISR and core maritime force functions. Army long-range precision fires, Air Force bombers and strike aircraft, and Navy surface fires capabilities are all under the control of the Surface Strike C2 element.

The Integrated Air and Missile Defense C2 element is given control of Army missile defense batteries as well as a subset of fourth and fifth generation aircraft, drawn from both the Air Force and Navy, to be used for defensive counter-air and cruise missile defense. Specific cyber capabilities are divided up across the operational C2 elements as appropriate based on their functions. Cyber capabilities relevant to degrading adversary Integrated Air-Defense Systems (IADS) are provided to the Ground Strike C2 element to facilitate strike using bombers and strike aircraft. Capabilities for degrading adversary ballistic missile avionics are provided to the Integrated Air and Missile Defense C2 element.

Once the operational C2 elements are stood up, each begins to process the lists of tasks assigned to it. The Surface ISR C2 element must allocate its resources to search across the distributed island chain for high-value relocatable ground systems, for wide area surveillance looking for adversary naval vessels, and holding imaging resources in reserve to respond to cues from wide area sources, both airborne and space-based. Initially, airborne ISR elements are held outside the range of potential threat from the islands themselves and are used for wide area search to detect adversary naval vessels that might be advancing beyond the islands. Space imaging assets are used to search areas of the islands that have been pre-determined to be likely operating locations for both enemy air defense and mobile ballistic missile systems. After receiving a Moving Target Indicator (MTI) detection from an airborne ISR system of a possible adversary naval vessel, an imaging task is created to generate a picture of the area around that MTI detection. The task is given a high priority and generates a re-plan of the ISR task/resource pairing.

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Before performing the re-plan, the Surface ISR C2 element requests an update from the Space Control C2 element on the threat level for the various satellites that might be available for providing ISR in the near term. The Space

BEFORE PERFORMING THE RE-PLAN, THE SURFACE ISR C2 ELEMENT REQUESTS AN UPDATE FROM THE SPACE CONTROL C2 ELEMENT ON THE THREAT LEVEL FOR THE VARIOUS SATELLITES THAT MIGHT BE AVAILABLE FOR PROVIDING ISR IN THE NEAR TERM.

Control C2 element provides its current risk assessment for satellites of interest. Given it is daytime with no cloud cover in the region, the re-plan results in the next electro-optical (EO) small satellite coming over the horizon being tasked to image the expected location of the detected ship based on its velocity at the time of the MTI detection and the time lag from then until the satellite is overhead. Other available ISR options, such as sending a high-altitude Unmanned Aerial Vehicles (UAVs) into range to image the vessel or sending a nearby submarine to observe the region are rejected because of the threat to those systems from adversary air defense or anti-submarine warfare systems.

The Surface ISR C2 element also reports to the Space Control C2 element that it will be using that EO satellite for a high-priority task and requests that protection of that satellite be given priority until the task is completed. After the image is taken, a short delay occurs until the small satellite comes overhead of a ground station for direct downlink of the image, as neither laser communications crosslinks to move the image instantaneously nor machine vision on board the satellite have yet been implemented on the EO constellation. The image is sent to an exploitation cell, which quickly identifies an adversary destroyer and provides coordinates accurate enough for targeting. A strike task is created and passed to the Surface Strike operational C2 element.

In parallel with the activities described above, the Surface Strike C2 element has been executing a plan largely focused on known fixed targets in the island chain and nearby littorals. As the status of the adversary integrated air defense system is unknown, but expected to be fully functional, the primary means of strike are long-range precision weapons that do not put manned aircraft at risk. As each of those targets is struck, the C2 element creates imaging tasks of lower priority to be sent to the Surface Surveillance C2 element for battle damage assessment. Once the adversary destroyer is detected and identified, a strike re-plan occurs.

The Surface Strike C2 element receives estimates from an Army missile battery, equipped with both anti-ship missiles and hypersonic missiles, operating from nearby friendly islands and from an Air Force B-1 bomber equipped with Long-Range Anti-Ship (LRASM) anti-ship missiles on combat air patrol. Based on the high cost of the hypersonic missile and the threat to the B-1 if it closes within adversary air defense range, the Army fires unit is immediately tasked with striking the destroyer with an anti-ship missile, given the ship is within engagement range. A machine-to-machine task is generated from the Surface Strike C2 element and sent to the Army battery controllers. The Surface Strike C2 element also reports to the Integrated Air and Missile Defense (IAMD) C2 element that the fire mission is being executed.

Before the start of hostilities, the IAMD C2 element had already developed a preliminary plan for deploying limited missile defense systems such as Patriot and Terminal High-Altitude Defense. Those plans were based on running multiple simulations of the scenario using the same machine-based algorithms used to generate resource/task pairing plans in operations. In the simulations, the distribution of the missile defense batteries was varied in random ways and the outcome of the scenario was measured. That data was then used to train a machine learning algorithm to place the batteries and iterated via simulation again and again with different adversary standoff weapons employment strategies. Those results were used to develop the Combined/Joint Force IAMD deployment strategy for friendly force protection. During the operation, the IAMD C2 element is assigned the mission of protecting high-value assets.

As the operation progresses, the adversary air defense systems continue to be used to maintain the threat A2/AD bubble. Periodically, those systems are observed by small satellites on orbit and strike missions are tasked to high-speed weapons from U.S. naval vessels or aircraft operating beyond threat engagement ranges. As adversary air defense systems are successfully engaged, the performance estimates provided from bomber and strike aircraft start to reflect higher confidence in the ability to successfully complete strike missions, until eventually the probability of successful missions and platform survivability rises high enough so that the Surface Strike C2 element plan includes sending a pair of B-2s equipped with 2000-lb Joint Direct Attack Munitions (JDAMs) over the islands to attack the air defense and missile garrisons. Once those missions are completed imaging tasks for Battle Damage Assessment (BDA) are sent to the Surface Surveillance C2 element. Those images show that the garrisons have been successfully destroyed and the threat from the island chain is assessed to be negated.

The commander reflects on the speed, precision, and success of the day's operations. The ability to bring all-domain effects to bear in mass and scale rapidly brought down exquisite standoff capabilities and centralized C2 structures of the adversary forcing them to pause and consider de-escalation options. JADC2 enabled collaborative employment of distributed forces and mission partners across all domains and battlefield functions. A resilient C2, data, and network architecture provided end-to-end interoperability on demand and machine-to-machine communications necessary to establish all-domain kill chains. This provided the commander the ability to aggregate combat power and apply effects as domain windows of opportunity and positional advantage were achieved. The improved decision speed resulting from information advantage allowed the force to deliver massed effects within operationally and tactically relevant timelines and allowed the commander to find and destroy high-value relocatable targets that posed significant threat to the force and homeland.

A RESILIENT C2, DATA, AND NETWORK ARCHITECTURE PROVIDED END-TO-END INTEROPERABILITY ON DEMAND AND MACHINE-TO-MACHINE COMMUNICATIONS NECESSARY TO ESTABLISH ALL-DOMAIN KILL CHAINS.

Summary

As demonstrated in the operational vignettes, increased effectiveness and efficiency in Joint C2 can be realized through innovation in traditional C2 organizational design and the application of advanced technologies that seek to achieve and sustain information and decision supremacy over the adversary. Artificial intelligence, machine learning, human-machine teaming, advanced visualization, data analytics, and machine-to-machine coupling work in concert to optimize the C2 cycle. ADOCs and battle management teams exploit all available data to establish a shared, clear understanding of the situation, mission, available resources, and commander's intent.

The commander executes decentralized C2 of distributed operations as the foundation for resilient C2 in a contested fight – an asymmetric advantage. An agile, tailorable C2 design that is based on mission and/or functional need supports dynamic operations enabled by conditions-based authorities. Optimized use of available resources through human-machine teaming and machine-to-machine communications achieves maximum combat effects.

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