Implementing Decision-Centric Warfare: Elevating Command and Control to Gain an Optionality Advantage

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Since the Cold War ended, the US Department of Defense (DoD) has developed doctrine and capabilities predominantly for the most stressing campaigns it could face against opponents such as the People’s Republic of China (PRC), Russia, and North Korea. These worst-case scenarios are intended to ensure US forces can address "lesser-included" cases as well. This approach, however, favors concepts and systems designed for large-scale, high-intensity military conflict, and intelligent US adversaries are unlikely to present US forces with confrontations where DoD could leverage its strengths in missions such as power projection or precision strike.

America’s rivals have evolved approaches during the past decade to circumvent US military strengths, such as PRC and Russian gray-zone or hybrid operations, that obtain objectives at lower cost and escalation—albeit over longer timeframes—than traditional military combat. DoD should therefore revise its planning to raise the priority of new scenarios that stress the US military in different ways than theater-wide high-intensity combat such as through protraction, varying levels of escalation and scale, and the use of proxy and paramilitary forces.

The People’s Liberation Army (PLA) concept of System Destruction Warfare and the Russian military’s New Generation Warfare are representative of the new approaches being employed against the United States and its allies. Although they are very different in their theory of victory and methodology, both concepts share a focus on information and decision-making as the main battlegrounds for future conflict. They direct attacks on an opponent’s battle network electronically and physically to degrade its ability to obtain accurate information while introducing false information that erodes the opponent’s ability to orient. Simultaneously, military and paramilitary forces would present dilemmas to the opponent by isolating or attacking targets in a manner that neutralized their combat potential and controlled the escalation of a conflict.

The Rise of Decision-Centric Warfare

Decision-centric concepts like Systems Destruction Warfare and New Generation Warfare will likely be a significant, if not predominant, form of future conflict. During the late Cold War, the US military’s revolutionary approach to precision-strike warfare leveraged the then-new technologies of communication datalinks, stealth, and guided weapons. Similarly, decision-centric warfare may be the most effective way to militarily exploit artificial intelligence (AI) and autonomous systems, which are arguably today’s most prominent technologies.

An example of decision-centric warfare is Defense Advanced Research Projects Agency’s (DARPA) Mosaic Warfare concept. Mosaic Warfare’s central idea is that disaggregated manned and autonomous units guided by human command with AI-enabled machine control could use their adaptability and apparent complexity to delay or prevent adversaries from achieving objectives while disrupting enemy centers of gravity to preclude further aggression. This approach is consistent with maneuver warfare, and differs from the attrition-based strategies employed by Allied forces during the Second World War and by the US military during post-Cold War conflicts in Kosovo, Iraq, and Libya. Although Mosaic Warfare employs attrition as part of creating dilemmas for enemies, its primary mechanisms to realize success are denying, delaying, or disrupting adversary operations rather than eroding an opponent’s military power to the point where it can no longer fight effectively. Mosaic Warfare is therefore well suited as a concept for status quo military powers, such as the United States, seeking to deter aggression.

Mosaic Warfare proposes a force design and command and control (C2) process that would enable US forces to execute more numerous and diverse courses of action (COA) compared to today’s US military. The mosaic force’s disaggregated structure and use of human command with machine control would complicate the opponent’s decision-making, narrowing its options and imposing a potentially insoluble set of dilemmas. By growing the options for US commanders and reducing them
for the enemy, Mosaic Warfare would seek to gain an “optionality advantage” that enables the US force to make faster and more effective decisions.

An optionality strategy stands in contrast to a forecast-centric planning approach, in which the COA most likely to result in success is chosen and implemented promptly to improve efficiency by allocating systems and force elements associated with unselected COAs to other missions. The early commitment of resources in the forecast-centric model necessarily constrains the option space available to commanders in the future. Compared with today’s US military, the mosaic force design and C2 process could provide a greater advantage in an optionality competition by mitigating the natural trend, due to losses or improved enemy situational awareness, toward fewer options as a confrontation or competition progresses. For example, mosaic forces could more easily conceal platforms or formations with counter-ISR capabilities and reveal them later to enable new options; draw upon a larger number of smaller and less-costly reinforcements; or rely on decision support tools to allow continued employment of units that are cut off physically or electronically from senior commanders.

A mosaic force would also be better able than today’s US military to conduct operations that narrow the opponent’s options. By mounting many simultaneous actions and accelerating its decisions, a distributed force using human command and machine control could impose sufficient dilemmas on the adversary to preclude an operationally relevant number of COAs. Furthermore, a mosaic force could complement its greater scale and pace of decision-making with deception techniques such as distribution, feints and probes, and counter-ISR systems that can convince an opponent certain options are not viable or unlikely to succeed.

Although DoD C3 constructs such as Combined and Joint All-Domain Command and Control (CJADC2) are beginning to incorporate decision support tools that integrate effects chains for a mission, their current and near-term instantiations are designed to support efficient delivery of fires rather than sustained optionality. Moreover, CJADC2-related C2 and communications (C3) initiatives such as the Advanced Battle Management System (ABMS) require the architecture and component systems to be defined in advance. As a result, CJADC2 will be inherently constrained in the level of optionality it is able to provide.

**Achieving Optionality through C3**

Within the C3 portfolio, DoD already makes sizable investments in communications resilience. The majority of new effort and resources should therefore be applied to C2 capabilities. Although the US military invests in what it calls C2 systems, these programs are predominantly operations centers and stacks of software that act as a substrate for passing data, information, commands, or authorities across a force. Although necessary to manage the force, current DoD C2 systems—which view C2 as connectivity—are not decision support systems, which view C2 as a process.

C3 capabilities for decision-centric warfare will need to do more than enable connectivity. For example, C2 tools will need to generate COAs that create and sustain optionality to improve adaptability and impose complexity on an adversary. To help junior leaders execute mission command, C2 tools would also need to understand which units are in communication, their role in potential COAs, and configure networks to ensure the needed units are aligned with the appropriate commanders. To assess these requirements and others for decision-centric C3, this study uses multiple perspectives, described below.

**Stack view:** Like the Internet, decision-centric C3 architectures will need physical mediums for the movement of data; network structures to manage the movement of data between commanders, sensors, and effectors; information architectures to organize data into meaningful forms; and applications to
assess information such as decision support tools. Current technologies could meet these needs but would not enable dynamic composition and recomposition of forces and networks in an adversarial environment while pursuing an optionality advantage.

**Network view:** Enabling optionality and implementing decision-centric warfare will require the ability to align C2 structures with available communications, rather than attempting to build a network that will survive in the face of concerted adversary jamming and physical attack. These needs lead to a hybrid architecture that combines a network approach with a hierarchical approach, which could be characterized as “heterarchical.” This topology would align command with the node having the highest degree among those occupied by a qualified human operator.

**Problem-solving view:** A problem-solving process using analogous reasoning could more quickly assess potential options than addressing each new situation from scratch, and the resulting increase in decision space could enable commanders to defer COAs that would constrain their options until the last possible moment. Moreover, if an AI-enabled algorithm is used to build COAs without the benefit of supervision, an adversary could influence the algorithm’s learning through feints and probes that make the system believe COAs were successful that actually would have failed if not for the adversary’s actions.

**Time view:** The concept of optionality applies over multiple timescales, from strategy through industrial capability development and tactical operation of the force. The capabilities of C3 architectures should help expand the decision space made possible by efforts across each timescale, rather than only during missions.

**Organization view:** DoD’s C3 architectures do not exist in a vacuum. They must be employed by personnel in organizations through processes in strategic, industrial, operational, and tactical timescales. Optionality is key to gaining an advantage in decision-centric warfare, but simply fielding a more disaggregated force and the tools to use it will only marginally increase the US military’s complexity and adaptability if the force is used in a narrow set of ways that provide the highest probability of success for each individual operation. Decision-making organizations and processes are needed that expand the option space available to commanders for as long as possible.

Today’s Combatant Commander (CCDR) staffs lack the organization and processes to compose forces in a wide variety of configurations for imminent missions. To enable composition of forces in mission time, DoD could use an approach similar to that employed to compile computer programs into executable code. Software instructions are written in a higher-level computer language but need to be converted into binary form before the software can be executed by the computer’s processor. This approach would start with a COA from a decision support system and then combine appropriate units to support the operation. Although force composition is primarily hardware-focused, it also entails the software composition of the force package in the information and network layers of the technology stack.

**Conclusion**

The US military will need to adopt new force designs and C2 processes to enable decision-centric warfare, but these efforts will come to naught if they are not combined with tools and organizations to fully exploit the optionality possible in a more disaggregated force operated using human command and machine control.

Current DoD efforts through CJADC2 and associated operational concepts to evolve US forces toward more distributed organizations and disaggregated capabilities are an essential step to enable a more decision-centric approach to military operations. The Advanced Battle Management System...
(ABMS) and several DARPA programs are developing C2 tools and processes that would increase the optionality available to commanders using these more distributed forces. DoD’s force design changes or C3 initiatives will need to go further for the US military to sustain an optionality advantage against peer adversaries that have already made the leap to decision-centric warfare and have a home field advantage from which to employ it.

Perhaps more importantly, new organizations and processes will be needed that allow CCDRs to compose and integrate disaggregated forces in theater and change the way DoD defines requirements and develops new capabilities. Without dramatic reforms to DoD’s requirements and force development processes, the US military risks falling behind adversaries in the competition for decision-making advantage, thereby threatening its ability to protect US interests and allies against great power aggression.
CHAPTER 1: THE EMERGENCE OF DECISION-CENTRIC WARFARE

The US Department of Defense (DoD) increasingly focused its doctrine and capability development during the past decade on great power opponents such as the People’s Republic of China (PRC) and Russian Federation or nuclear-armed regional powers like North Korea. The most stressing campaigns US forces could face against these adversaries dominated DoD planning, with the assumption that worst-case scenarios also capture the needs for “lesser-included” cases. Recognizing DoD’s focus on high-intensity warfighting, however, adversaries are methodically developing strategies and systems that circumvent the US military’s strengths and exploit its vulnerabilities by avoiding the types of situations for which US forces have prepared.

As part of their efforts to asymmetrically counter US military strengths, operational approaches being pursued by the PRC and Russian militaries share an emphasis on information and decision-making as the main battlegrounds for future conflict. Concepts such as the People’s Liberation Army’s (PLA) System

Photo Caption: Sea Hunter, a new class of unmanned sea surface vehicle developed in partnership between the Office of Naval Research and the Defense Advanced Research Projects Agency, completes an autonomous sail from San Diego to Hawaii and back, the first ship ever to do so autonomously. Sea Hunter is part of ONR’s Medium Displacement Unmanned Surface Vehicle project. (US Navy)
Destruction Warfare or the Russian military’s New Generation Warfare direct forces to electronically and physically attack an opponent’s ability to obtain accurate information while introducing false data that erodes the defender’s ability to orient. Simultaneously, the aggressor’s military and paramilitary forces isolate or attack targets without escalating the conflict in ways that could provide a pretext for large-scale US and allied military retaliation. The dilemmas posed by degraded information and an inability to employ traditional US military responses could enable aggressors to achieve their objectives without resorting to attrition as the primary success mechanism.

Decision-centric concepts like those pursued by the PRC and Russian governments will likely be a significant form of future conflict, especially as more confrontations occur outside the context of large-scale existential combat. When a government’s survival is at stake, its leaders would be more likely to adopt attrition-based approaches in an attempt to avoid defeat. Although decision-making and information would remain important when a conflict becomes attritionary, the lethality and survivability of individual units could be equally decisive.

During the late Cold War, the US military’s revolutionary approach to precision-strike warfare leveraged the then-new technologies of communication datalinks, stealth, and guided weapons. Similarly, decision-centric warfare may be the most effective way to militarily exploit artificial intelligence (AI) and autonomous systems, which are arguably today’s most prominent technologies. An example of this approach is the Defense Advanced Research Projects Agency’s (DARPA) Mosaic Warfare concept, which combines AI-enabled command and control (C2) with forces that achieve greater disaggregation than today’s US military by incorporating a larger proportion of autonomous systems.

Mosaic Warfare’s central idea is that disaggregated manned and autonomous units guided by human command with AI-enabled machine control could use their adaptability and apparent complexity to delay or prevent adversaries from achieving objectives while disrupting enemy centers of gravity to preclude further aggression. This approach is consistent with maneuver warfare, and contrasts Mosaic Warfare with attrition-based strategies employed by Allied forces during the Second World War and by the US military during post-Cold War conflicts in Kosovo, Iraq, and Libya. Although Mosaic Warfare employs attrition as part of creating dilemmas for enemies, its primary mechanisms to achieve objectives are denying, delaying, or disrupting adversary operations rather than eroding an opponent’s military power to the point where it can no longer fight effectively.

Although they share a common foundation, Mosaic Warfare builds on maneuver warfare by proposing a force design and command and control (C2) process that would enable the US military to execute a larger and more diverse set of courses of action (COA) compared to an opponent. In a decision-centric confrontation, the force with such an “optionality advantage” would be more likely to impose an insoluble combination of dilemmas on the adversary.

Mosaic Warfare would also differ with maneuver warfare in terms of its scope and timeframe. Whereas maneuver warfare is viewed as a tactical and operational-level military concept, Mosaic Warfare’s force design and C2 approach would yield optionality advantages at the strategic level as well as in the development and fielding of new capabilities before a confrontation begins.

As will be described below, the US military is already adopting many of the elements of mosaic force design. Therefore, this report will focus on the needs for C2 of decision-centric warfare, starting in Chapter 2 with a proposed framework for evaluating C2 and communication (or C3) requirements. DoD’s current efforts for meeting future C3 requirements are addressed in Chapter 3 and the needs for decision-centric concepts, including Mosaic Warfare, are described in Chapter 4.
Force Design
To increase optionality, mosaic force design would replace a portion of the US military’s monolithic, self-contained platforms and units with a larger number of smaller, less-expensive, and less multifunctional units and systems. Although these smaller units may have less endurance, self-protection, or capacity than the elements of today’s force, they could be deployed or escorted into theater by multimission platforms and considered attritable or expendable in combat. Figure 1 shows how a mosaic design approach could be implemented in the US Navy’s force structure, which increases the overall number of vessels without growing procurement or sustainment costs. The Navy and other US military services are already moving in the direction of more distributed force structures that are consistent with mosaic force design.

Figure 1: Example of how the US Navy could be rebalanced to implement Mosaic Warfare force design principles

The current and proposed future force cost approximately the same amount to buy and operate, incorporating inflation.

The greater number and diversity of units in a mosaic force would provide more potential combinations to commanders, allowing them to identify acceptable COAs faster and more easily select COAs that have a higher probability of success. The mosaic force’s disaggregation would also enable commanders to more precisely calibrate the capacity and capability of force packages, which could allow a force to be spread over a larger number of simultaneous tasks compared with today’s US military. From an opponent’s perspective, the mosaic force’s higher decision-making tempo, scale, and effectiveness compared to a traditional force would tend to foreclose more of the opponent’s COAs, further strengthening the mosaic force’s optionality advantage.

Rebalancing US forces toward a larger number of smaller platforms and formations creates operational benefits. The more disaggregated mosaic force would be better able to mount feints, probes, and other high-risk, high-payoff operations that would not be worth the potential loss of a monolithic, multimission platform or formation. Disaggregation would also enable more force package options that can proportionally counter gray-zone or subconventional aggression. In contrast, today’s US gray-zone responses either employ small numbers of expensive platforms at high risk of being overwhelmed adjacent to an adversary’s territory, or larger formations that can protect themselves but are likely disproportionate to the situation.

Across a longer competition, the smaller, less-multifunctional units in the mosaic force could more easily incorporate new mission systems and technologies compared to their monolithic, multimission counterparts. As a result, the mosaic force could adapt more quickly compared to today’s military by promptly fielding new sensors, radios, weapons, or electronic warfare systems as they emerge from research and development instead of waiting for costly and time-consuming integration.

**Command and Control**

The staff-managed and doctrine-driven C2 process of today’s military is too slow and lacks the capacity to rapidly develop COAs that integrate a large number of disaggregated units in performance of changing missions. The mosaic C2 approach addresses the shortfalls of staff-driven planning by combining human command with machine control, in which human commanders identify tasks, set constraints and priorities, and identify forces available for use; machine-enabled decision support systems then develop proposed COAs that support the commander’s intent. Together, a more disaggregated force and a machine-enabled C2 process would enable faster decision-making at scale, as evidenced in the wargame performance of mosaic teams shown in Figure 2.

Human command and machine control would also support the US military concept of mission command, in which subordinate leaders rely on their own initiative and creativity to pursue the intent of senior commanders when communications are lost. As US forces become more disaggregated or distributed, junior commanders will be less able to creatively employ units and systems under their control without planning staffs. As a result, junior commanders cut off from headquarters could fall back on habit or tactics that are predictable by the enemy. Decision support systems would avoid this loss of optionality by enabling junior commanders to effectively improvise and create unexpected COAs when communications are degraded.

**Technologies for Decision-Centric Warfare**

DoD is pursuing elements of decision-centric warfare as part of its new Combined and Joint All Domain Command and Control (CJADC2) construct. Each US military service is introducing more unmanned systems, rebalancing toward a larger number of smaller platforms or formations, and embracing disaggregated effects chains. CJADC2 provides an overarching framework for these efforts as well as the new Joint Warfighting Concept that employs a more distributed force structure. Some new technologies are needed to enable DoD’s emerging force designs, such as autonomous vehicle
controls, network management systems, and small form-factor sensors or effectors. However, these efforts are well-supported and reaching a high level of maturity.

Given DoD’s progress on fielding more disaggregated forces, C2 should be the focus of technology development for decision-centric warfare in general and Mosaic Warfare in specific. The technology for human command and machine control is already emerging from DoD initiatives designed to support specific military missions such as air-to-air combat or missile defense. C2 technology development will need to build on these programs and enable management of an entire force across multiple missions against adversaries that are actively attempting to undermine US decision-making.

In contrast to the playbooks and tactics used in today’s operational planning, realizing the greater optionality inherent in the mosaic force design will require decision support systems that can rapidly analyze numerous potential COAs and adversary responses, providing commanders an assessment of each COA’s likelihood of success and how it may impact the opponent’s decision space. Perhaps most importantly, C2 tools for decision-centric warfare will need the ability to develop and consider COAs outside the bounds of previous engagements or doctrine to surprise an opponent with an unexpected action or respond to an unlikely enemy operation. Some DoD programs are already pursuing the algorithms needed to support this approach to “changing the game” on an opponent.

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Figure 2: Comparison of task completion between mosaic forces and traditional military forces in recent wargames

Over a longer conflict, C2 tools will also need to help commanders understand how they can orchestrate individual engagements to implement their strategy and maintain an optionality advantage. For example, a commander can initially use a large number of simultaneous operations, including numerous feints and probes, to overwhelm enemy decision-making and narrow its decision space. Using the information gained from their opening actions, US forces could then execute a focused set of attacks against primary targets while pursuing suppression operations against enemy forces using attritable units with a high likelihood of loss. The US commander could close the mission by mounting a series of unexpected COAs against remaining targets to constrain the enemy’s options and keep it off balance until the US force accomplishes its objectives. A decision-centric C2 tool should aid commanders in considering a series of COAs like these against a range of enemy responses.

Forces conducting decision-centric warfare will require a complex set of C2 and communications capabilities to fully exploit the optionality possible with a more disaggregated force design and narrow the COAs available to opponents. The next chapter will develop a framework for assessing decision-centric C3 technology needs. Using this framework, specific requirements for C3 capabilities for gaining an optionality advantage will be described in Chapter 4.
Current US military C2 doctrine relies on hierarchical structures in which command and control are centralized with a senior commander and orders, resources, and authorities are passed down a chain of command to enable decentralized execution. This hierarchical approach works well when communications are generally available over the commander’s area of responsibility (AOR) and of sufficient throughput to transmit sensor data, analytics, orders, and feedback. When communications are degraded, junior leaders are expected to exercise mission command.

However, DoD has failed to field decision support capabilities that could enable junior leaders to execute missions using the US military’s growing diversity of disaggregated units when communication shortfalls prevent reliance on staffs at higher headquarters. The C2 systems emerging from current R&D efforts such as the Army’s Project Convergence, the Navy’s Project Overmatch, or the Air Force’s Advanced Battle Management System (ABMS) are only able to integrate relatively small numbers of units during tactical engagements. More importantly, junior commanders need decision support tools that help them gain an optionality advantage against the enemy, which has not been a priority of current DoD C2 initiatives.

Given the likelihood of contested electromagnetic operational environments (EMOE) during future conflicts, US forces will increasingly depend on mission command. DoD should therefore pursue a more holistic C3 approach in which communications investments are balanced against those for C2 tools. Mosaic Warfare characterizes this approach as context-based C3, which reverses DoD’s normal priority of communications requirements supporting an intended C2 structure to instead adapt C2 relationships based on communications availability.

Refocusing C3 on C2

Within the C3 portfolio, DoD already makes sizable investments in communications resilience. The majority of new effort and resources should therefore be applied to C2 capabilities. Although the US military invests in what it calls C2 systems, these programs are predominantly operations centers and stacks of software that act as a substrate for passing data, information, commands, or authorities across a force. Sometimes, C2 programs are extended to include communications, computers, cyber, and intelligence, surveillance, and reconnaissance (ISR) sensors.
(CISIR); these are essentially battle networks, or a set of components for creating and sharing information and direction via a communications system. Although necessary to manage the force, battle networks—which view C2 as information sharing—are not the same as decision support systems, which view C2 as a process.

DoD’s emphasis in C3 on networks rather than C2 processes reflects an expectation that the entire operational force can be connected, providing senior commanders situational awareness of the relevant battlespace and the ability to direct action by any friendly unit within it. This approach was first defined in the concept of Network-Centric Warfare during the 1990s and continues today in the characterization of CJADC2 by some military leaders. Under Net-Centric Warfare, senior commanders and their staffs could direct efficient theater-level campaigns using their comprehensive picture of the operational area and communications with all relevant forces.
Network-Centric Warfare is not well-suited to an adversarial context. The improving jamming capabilities of peer competitors are likely to prevent continuous theater-wide high or moderate bandwidth communications. The efficient and optimized allocation of forces would be disrupted, and Network-Centric Warfare would likely devolve to junior commanders exercising mission command by relying on doctrine and habits that are known to an enemy.

To avoid the vulnerabilities of Net-Centric Warfare, decision-centric concepts emphasize C2 capabilities alongside the communication systems that enable it. In Mosaic Warfare, C2 consists of human commanders setting bounds and establishing objectives for machine control systems, which propose COAs to achieve the commanders’ intent. Despite the advantages possible with machine-assisted planning, there is no automated replacement for humans in setting the objectives and bounds for an operation or establishing an overall strategy for a campaign. Unlike a machine, humans can also be accountable for the results and consequences of decisions.52

The mosaic C2 approach can be viewed in the context of Colonel John Boyd’s observe, orient, decide, act (OODA) loop for military operations, which has been adapted to a wide variety of military and commercial contexts. As shown in Figure 5, the proliferation of sensing may prevent either side from gaining an edge in...
observation, requiring mosaic C2 operations to gain an advantage using other parts of the OODA loop. In its own decision cycle, a mosaic force would increase the scale of decision-making by distributing its disaggregated units across more simultaneous actions and accelerate decision-making using computer-based tools that exploit the mosaic force’s larger number of options compared to the enemy. Mosaic forces would undermine the enemy’s OODA loop and narrow its options by creating more complex or confusing postures that degrade the opponent’s orientation and generating a scale of friendly decision-making and action that overwhelm the enemy’s ability to effectively act.

C2 in an adversarial context also requires ways to address uncertainty. Outcomes from friendly actions depend on adversary responses and countermeasures and enemy operations could reveal new opportunities or vulnerabilities to be exploited later. Decision-making processes that keep the commander’s options open, rather than narrowing down a commander’s choices to a few feasible COAs, could help a force adapt and succeed under conditions of uncertainty. More friendly options also create more uncertainty for an opponent, which may provide an advantage if the enemy’s planning process cannot easily adapt.

The agility afforded by the mosaic force design and C2 process would enable a decision-making process that explores and assesses a wide range of options, providing commanders potential COAs with varying probabilities of success and different impacts on the availability of future options. Instead of encouraging an early downselect to a single course of action, decisions could be made that preserve a broad envelope of future possibilities. This approach stands in stark contrast to today’s staff-driven planning process, which deterministically pursues a small set of optimized solutions for commanders to consider. The lack of optionality in today’s planning is partly a function of today’s reliance on monolithic multimission platforms and manual planning processes, but also reflects the inevitable impact of human cognitive biases toward COAs that worked in the past or align with doctrine.

Like modern business management techniques such as Lean Six Sigma, today’s DoD C2 processes are well-suited for static non-adversarial problems with a single solution or narrow range of solutions. These approaches, however, fall short in the face of adversary action because they cannot maintain the optionality to adapt the force or impose complexity and uncertainty on an opponent. DoD will need to evolve its C2 processes to focus on maximizing the range of COAs available to commanders.

Optionality: The Goal of Decision-Centric C3

In business, an optionality or antifragility strategy is designed to grow or sustain the range of options available to leaders. This approach can make a business more adaptable in the face of uncertainty, but incurs a reduction of efficiency and risks taking a company’s focus away from the core strengths that made it successful. In an adversarial military context, the cost and inefficiency associated with adaptability are likely worth incurring because optionality also creates complexity and uncertainty for an opponent.

Mosaic Warfare harnesses optionality to enable faster and more effective decision-making and action while degrading enemy orientation. Although DoD C3 constructs such as ABMS are beginning to incorporate decision support tools that integrate effects chains for a mission, their current and near-term instantiations require the architecture and component systems to be defined in advance. As a result, CJADC2 will be inherently constrained in the level of optionality it is able to provide.

More advanced C2 tools than those in ABMS today could help enable an optionality strategy by providing commanders an understanding of the available decision space and how it is likely to change as a result of different COAs. A commander assessing a proposed COA in Mosaic Warfare could consider the COA’s predicted probability of success, its required resources and anticipated losses, and the number of future options it will eliminate or potentially create. For example, a commander may
choose a COA providing a relatively low probability of success if it forecloses fewer future options than other COAs to keep the option space open. Alternatively, a commander could pursue a probe or feint that has a low likelihood of succeeding but could create more options in the future by revealing an opponent’s capabilities, tactics, or intent.

The ability to maximize optionality would provide operational and strategic benefits. In the lead-up to conflict, an aggressor may be unable to quickly characterize the mosaic force due to its complexity and adaptability, reducing the aggressor’s confidence and dissuading it until conditions improve. A mosaic force’s disaggregated nature would enable frequent probes against an enemy and aggregating or massing units when gaps are detected or created to exploit the opening.

The mosaic force design and C2 process would enable an optionality strategy to be applied not only in current missions at the tactical and operational level of war, but also over longer strategic and industrial timeframes. By disaggregating units into smaller, less multifunctional elements, decision-centric force design enables greater variety in the systems developed by military services compared to highly integrated monolithic platforms and formations that can only be configured in a small number of ways. Mosaic forces would also allow services to provide a wider diversity of force combinations to operational commanders.
Higher optionality in force development and management could, in turn, allow greater flexibility in defense strategy.

An optionality strategy stands in contrast to a forecast-centric planning approach, in which the COA most likely to result in success is chosen and implemented promptly to improve efficiency by allocating systems and force elements needed for other COAs to other missions. The early commitment of resources to missions in the forecast-centric model necessarily constrains the option space available to commanders in the future. The most significant problem with a forecast-centric approach is its dependence on assumptions regarding future scenarios and US and adversary capabilities, postures, and objectives. If these assumptions prove incorrect, the forecast is wrong, and the narrowed decision space is centered around the wrong set of choices. For example, DoD often addresses the possibility its forecasts are wrong by attempting to prepare for the most stressing scenarios and assuming other situations will be lesser-included cases. A significant flaw in preparing for the worst-case situation is that less-intense scenarios such as gray-zone operations may be stressing in ways other than strictly combat and attrition. Protracted confrontations can stress the force’s capacity, demand non-military instruments of national power, and require smaller, more proportional units that are not widely available in the current US military. An optionality strategy, in contrast, would be able to conduct a wide range of COAs. Although it would not be optimized for any particular situation, the decision-centric force would be able to contend with a greater variety of scenarios and may be able to execute COAs that drive the situation in a more favorable direction for US forces.

In addition to its apparent efficiency, a forecast-centric approach is attractive because it allows senior leaders to align a commander’s authorities with his or her planned operations. Unfortunately, this benefit requires a hierarchical C2 construct and static plans that are not adaptable in the face of adversary action. A decision-centric concept like Mosaic Warfare that exploits optionality will require commanders to have a wider array of authorities than those used in today’s forecast-centric operations. Moreover, in context-based C3, the commander choosing COAs and guiding option development for a force would change with communications availability, requiring flexible delegation of authorities.

Gaining an Optionality Advantage

As shown in Figure 6, the optionality available to a commander will often decrease during a mission or campaign as force elements are expended or attrited and proximity to the enemy constrains the maneuver space and number of force elements that can be relevant to the operation. Optionality will therefore form one of the main arenas for competition in decision-centric conflict. As depicted in Figure 7 for the DARPA Prototype Resilient Operations Testbed for Expeditionary Urban Scenarios (PROTEUS) program, each combatant will attempt to sustain more options than its opponent by deferring commitment to limiting COAs and foreclosing adversary options by attacking key nodes, reducing situational awareness, or degrading C3.

Compared with today’s US military, the mosaic force design and C2 process could provide a greater advantage in an optionality competition by mitigating the natural trend toward fewer options as a confrontation or competition progresses. For example, mosaic forces could more easily conceal platforms or formations with counter-ISR capabilities and reveal them later to enable new options; draw upon a larger number of smaller and less-costly reinforcements; or use context-based C3 in contested electromagnetic environments to allow continued employment of units that are cut off physically or electronically from senior commanders.

A mosaic force would also be better able than today’s US military to conduct operations that narrow the opponent’s options. By mounting many simultaneous actions and accelerating
The analytics and user interface show the optionality advantage for Blue and Red forces over approximately 200 human vs. human matches. Friendly (blue) forces have a decision advantage when they have more options available (blue area in plot) than the enemy (red area).

As shown from left to right on the bottom of the figure:

- A Force of Today (FOT) makes contact with a Red Force indirect fire kill chain employing a sniper unit equipped with electronic attack capabilities. Blue has a persistent disadvantage for EM fires since it has no electronic attack capability. Blue is only able to construct an indirect fire kill chain if the ISR UAS is able to relay targeting to the mortars via infantry deploying it through HQ to the Blue mortars.

- A mosaic force has a richer array of risk-worthy unmanned systems with multifunctional payloads capable of functioning as communications relays, electronic attack, or ISR. An unaided human commander is challenged to coordinate and execute a multi-domain combined arms attack. This is shown by the negative optionality relative to Red after contact. This limited optionality results from Red jamming (as shown in the map UI) of ISR and the delay in effectively coordinating indirect fires.

- A mosaic force with machine control ("EMSO Wizard") is able to reliably coordinate multi-domain attacks through dynamic composition of communications, targeting, and both kinetic and EM fires, resulting in consistent Blue option advantage.

Source: DARPA, John Paschkewitz, Analytics and UI from DARPA PROTEUS program AI-assisted planning/wargaming tool.
its decisions, a distributed force using human command and machine control could impose sufficient dilemmas on the adversary to preclude an operationally relevant number of COAs. Using distribution, feints and probes, and counter-ISR systems, mosaic units would also be better suited than today’s US military to execute deception strategies that can convince an opponent certain options are not viable or unlikely to succeed.

The combination of more composable forces and deception would enable mosaic forces to use substantially less effort to build effective COAs than the adversary is required to expend in response. This differential has an analog in modern encryption methods, which use “one-way” functions like the product of large prime numbers, which are easy to multiply and difficult to factor. Establishing an asymmetry in creating COAs would be an objective of each competitor in a decision-centric confrontation.

The US military has made the opening moves toward a more decision-centric C3 architecture with initiatives like ABMS and Project Convergence. These efforts, however, will need to substantially increase their emphasis on C2 and decision support tools for US forces to achieve the optionality needed to win future conflicts in which adaptability and decision-making are the determinants of success. The next chapter will address this needed evolution, and the subsequent chapters will describe the technological and organizational requirements that would enable it.
CHAPTER 3: DRIVING CJADC2 TOWARD OPTIONALITY

Rather than being an acquisition program in its own right, CJADC2 is an overarching construct for a collection of programs and concepts that enable communications connectivity between military units and dynamic C2 of their operations. Each military service is leading a cross-functional team to advance elements of CJADC2, which is intended to provide the C3 architecture for DoD’s emerging Joint All Domain Operations (JADO) warfighting concept. CJADC2 system development has thus far focused on connecting air and ground forces via ABMS, which is described by its developers as an Internet of Things for military operations. The Navy is not explicitly integrating its C3 efforts with ABMS, but is developing its own federated C3 architecture that will integrate with ABMS as part of CJADC2.

ABMS builds on longstanding DoD communication networks such as Link-16, Tactical Targeting Network Technology (TTNT), or Cooperative Engagement Capability (CEC), and will likely integrate with additional networks over time in a federated architecture designed to provide theater-wide communications. ABMS is also likely to leverage emerging communication

Photo Caption: Bradley Fighting Vehicles, known as Mission Enabling Technologies Demonstrators, and modified M113 tracked armored personnel carriers, or Robotic Combat Vehicles, are being used for the Soldier Operational Experimentation Phase 1 to further develop learning objectives for the Manned Unmanned Teaming concept at Fort Carson, Colorado in December 2020. (Jerome Aliotta)
management capabilities such as the DARPA Dynamic Network Adaptation for Mission Optimization (DyNAMO) program but is also developing new management systems as part of the Air Force’s MeshONE initiative.\textsuperscript{37}

Given its emphasis on communications connectivity, a significant portion of new ABMS-related investment is devoted to building interoperability between disparate networks. The Air Force and Army are pursuing capabilities as part of ABMS to connect networks using gateways through experimentation campaigns such as Project Convergence. As part of the overall CJADC2 initiative, the Navy’s Project Overmatch is also pursuing network interoperability and resilience outside of ABMS.\textsuperscript{38} With DoD research organizations, the Air Force is advancing automated software toolkits such as DARPA’s System of Systems Technology Integration Tool Chain for Heterogeneous Electronic Systems (STITCHES), which enable on-demand interoperability between systems that have never explicitly been programmed to work together.\textsuperscript{39}

ABMS is now also incorporating decision support aids, some of which were recently employed in a series of missile defense exercises. Although automated planning tools are key to the future vision of CJADC2, the ABMS C3 construct is likely to be relatively static in the near term. Rather than dynamically connecting units as they enter the operating area, in experiments the network supporting ABMS is established and maintained manually and potential elements of effects chains are selected and characterized by users in advance. When operations are needed, ABMS proposes a simple COA such as a weapon-target pairing and a timing or order of engagements, rather than exploring the entire set of COA options available to a commander.\textsuperscript{40}

**The Three Waves of Mission Integration**

Today, assembling a battle network—or a collection of sensors, shooters, and C2 nodes connected by a communication system—relies on manual establishment of communications between elements and a staff-driven planning process to integrate them in pursuit of a specific mission. This duty falls to Geographic Combatant Commanders (CCDR) and their components to perform in theater using the interoperability built into systems by military services and a few decision support tools to plan logistics or communications. The improvements in communication connectivity and decision support tools afforded by CJADC2 will only incrementally advance the speed or effectiveness of today’s C3 constructs. However, this first wave of mission integration toward the full implementation of decision-centric warfare will provide a noticeable improvement over legacy approaches to force packaging and COA development.

The relatively static nature of ABMS in the near term will not be sufficient to support the optionality needed for decision-centric warfare. But as it becomes able to dynamically compose battle networks and provide commanders decision support capabilities, ABMS will become inherently more adaptable and able to impose complexity on opponents. In this Wave 2 instantiation of DoD mission integration, ABMS would enable CCDRs, their components, and Joint Force Commanders (JFC) to more easily compose force packages and develop COAs for missions as well as reconfigure their forces during operational pauses. Improvements to decision support tools would provide commanders visibility into a broader set of potential options. The range of COAs available, however, will be limited by US force design, which could remain weighted for the next decade toward a small number of monolithic multimission units with little ability to disaggregate and recompose.

To enable Wave 2 mission integration, ABMS’ decision support systems will need to do more than simply propose weapon/target pairings and engagement schedules. To enable context-based C3, C2 tools will need to recognize which units are in communication with a commander and available for tasking, even as local commanders are cut off from higher
headquarters. Within the resulting local C2 structures, decision support systems will need to assess how COAs balance between objectives while staying within constraints set by the commander. For example, in addition to engaging enemy targets, COAs would need to defend friendly units, degrade the enemy’s situational awareness to narrow its options, and position friendly forces in ways that preserve decision space for the next set of missions.

Wave 3 of DoD mission integration would reflect the use of CJADC2 to fully implement decision-centric warfare. In addition to composing forces before a mission to address multiple competing objectives, C2 processes in Wave 3 would recompose forces in real time during an operation, enabling commanders to maximize their optionality advantage. In concert with C2 processes, Wave 3 of mission integration will require that greater adaptability and interoperability be built into systems before they are deployed to CCDRs. DoD will therefore need to change the ways it defines requirements and develops capabilities.

Requirements for new systems are currently identified through the Joint Capabilities Integration and Development System (JCIDS) to fill projected capability gaps in likely future operational situations. As an example of forecast-centric planning, the deterministic JCIDS approach depends on numerous assumptions regarding the future composition of US forces, adversary capabilities, and scenarios. Although the assumptions JCIDS analyses make about adversary capabilities and scenarios could be wrong, its characterization of the US
force is more likely to be accurate given the relatively static nature of today’s US system-of-systems architectures and warfighting doctrine.

A more disaggregated force like that employed for decision-centric warfare would be composed and orchestrated in ways that are unique to each new situation, preventing analysts using a forecast-centric planning process from making accurate projections about future US system-of-system configurations. Rather than seeking to address specific capability gaps, potential new capabilities should be assessed in terms of their impact on the performance of a variety of force packages in a wide range of situations.

A decision-centric requirements approach would therefore focus on opportunities for new capabilities to improve the potential future force, rather than attempting to predict and fill shortcomings. In contrast to the deterministic JCIDS process, a decision-centric requirements approach would be stochastic in that it will not yield one specific requirement but rather a range of probabilistic force-level performance improvements that will change depending on the scenario. The most advantageous capability investments would be those that afford the greatest optionality and performance over the largest number of relevant scenarios, similar to the value of operational COAs that maintain the widest decision space for commanders.

In Wave 3 of mission integration, the output of decision support tools could directly inform DoD requirements and acquisition processes by highlighting to operational commanders when a set of satisfactory COAs is not achievable. C2 tools could then be used iteratively between capability developers and operational commanders to assess potential new capabilities that are available or feasible in the near to mid-term and could provide better performance or increase the force’s optionality. In addition to informing development of more adaptive capabilities, this acquisition approach would also help to shrink the delay between need identification and system fielding. One potential instantiation of this process and organizational construct is described in Chapter 4.

**Designing C3 for Adversarial Environments**

DoD’s progress in Wave 1 of mission integration has centered on improving communications interoperability between existing networks through umbrella programs such as ABMS, the Army’s Integrated Battle Management Command and Control System (IBCS), and the Navy’s Communications as a Service effort. These R&D programs are complemented by service experimentation campaigns such as the Army’s Project Convergence and the Navy’s Project Overmatch that build effects chains between disparate networks in mission settings. As noted above, although they sometimes incorporate decision support systems as part of demonstrations, DoD C3 initiatives such as these put most of their effort on communications rather than C2.

The emphasis of DoD C3 programs on connectivity results in part from the growing number and diversity of government and commercial sensors, unmanned vehicles, and networked displays and controls available to military forces. A natural inspiration for building out a sprawling network of diverse, widely distributed systems providing services like sensing and remote actuation is the Internet, and ABMS is often described by Air Force leaders as the military Internet of Things (IoT).

Although it uses military-grade communications systems, basing ABMS on an IoT model has several potential pitfalls that would take it away from the focus on optionality needed to enable Mosaic Warfare and other forms of decision-centric warfare:

**Lack of Adversaries**

An IoT architecture is designed to share information and direct action in scenarios where environmental factors and security threats are the main challenges to performance. In military scenarios, environmental and security threats remain, but are joined by an opponent’s deliberate efforts to deceive or
degrade IoT performance and constrain the options available to friendly forces. For example, adversaries could introduce false or obscured sensor inputs, methodically and strategically disrupt or manipulate communications, or physically damage or destroy battle network components.

The wider range of challenges facing a military IoT architecture will require more sophisticated management functions to ensure the information and services most important for planned or potential operations are prioritized when the architecture is degraded. Military IoT architectures will also need to incorporate mechanisms to validate sensor information and communications to counter manipulation and deception or introduce human oversight to accept accountability for proceeding in the face of uncertain information.

A potentially more significant way in which the presence of an adversary makes military IoT architectures different from commercial constructs is the opportunity to gain an optionality advantage by degrading or manipulating an opponent’s decision-making while sustaining one’s own. Commercial IoT architectures are designed to maximize performance against measures such as data throughput, service continuity, or operational outcomes; this is only one side of the optionality competition in a decision-centric operation. Degrading the adversary’s decision-making may be a more efficient way to gain an optionality advantage compared with repositioning capabilities, bolstering logistics, or restoring communications to give friendly commanders more COAs from which to choose.

Extending the argument further, in some cases, undermining both friendly and adversary decision-making could yield a net gain in decision space for the combatant initiating the action. This was, for example, the approach used successfully by the German military during the Second World War to degrade Allied bombing by disrupting bombers’ radio navigation systems. Although German jammers also impacted the Luftwaffe’s communications and navigation, the consequence was minimal
because, as the defender, German interceptor aircraft could engage bombers using visual and radar targeting along the likely Allied lines of approach.\textsuperscript{44}

**Lack of Simultaneous, Competing Processes**

Commercial IoT architectures may incorporate a diverse array of services, but generally are designed to support control of a single process or multiple related processes. The narrow range of objective functions pursued by most IoT architectures allows their management systems to adjudicate between various services to satisfy the user demands.\textsuperscript{46} For example, a warehouse IoT architecture would need to select the right collection of robots and mobile or stationary sensors to move products from the loading dock to the shelves where they will be stored. Other functions, such as controlling ambient temperature or managing facility access, would not compete with inventory management operations in the IoT architecture’s decision-making.

Military IoT, in contrast, will always involve competing objective functions. For instance, a military IoT would often need to sense targets in the objective area, jam or decoy enemy sensors, engage enemy units or weapons that approach friendly forces, and consider how different COAs constrain or preserve future decision space. These objectives often directly compete with one another. Military IoT architectures will need to present different COAs to commanders that service to varying degrees the commander’s objectives, along with the potential consequences. Commanders will then need to select COAs with consequences that best align with their overall strategy.

**Bistatic, Rather than Dynamic, Information Flow**

Commercial IoT architectures generally are designed to transmit data to services and direction to IoT components. To support context-based C3 and mission command, military IoT architectures will need to support alternating directions of data flow as the locus of decision-making changes with the
availability of communications. Data flows will also change as sensors and communication nodes increasingly are able to make limited decisions that improve their performance or better support an overall mission.

For example, under context-based C3, a junior leader cut off from senior commanders may find herself in command of several fire teams and unmanned vehicles and able to communicate with a peer commander through a UAV that was previously used only as a sensor. In this new C2 construct, fire teams would need to send data to the junior commander rather than to higher headquarters. The UAV that was originally only sending sensor data would now also receive sensor data and send and receive messages as the two junior commanders coordinate their operations.

Addressing the limitations of IoT architectures will require that ABMS and other DoD C3 architectures incorporate decision support and communication management systems that can enable commanders to develop and select COAs for adversarial environments and manage changing communication flows and command relationships. The recent introduction of C2 tools into ABMS is encouraging, but unless these efforts are focused on specific objectives such as achieving an optionality advantage, the US military will perform well and efficiently at home but fail when it encounters a capable adversary.

**Summary**

Although decision-centric operational concepts like Mosaic Warfare, DMO, or EABO benefit from more disaggregated force designs, employing widely distributed units in ways that maximize optionality depend on new approaches to C3. Within C3, communications connectivity and interoperability are important, but can be degraded by enemy jamming or deception. Therefore, DoD’s ongoing efforts to improve communications resilience should be balanced against those to develop C2 or decision support tools that would allow commanders to make the best use of those forces with which they can communicate. DoD’s current initiatives through ABMS as part of CJADC2 are beginning to strike this balance.

The optionality of a military force, and the complexity it imposes on an enemy’s decision-making process, would likely be an important element in the operational strategy of a commander leading a force employing decision-centric concepts. In addition to helping commanders build COAs to accomplish tasks with their forces, C2 tools will need to help commanders understand the decision space available to them and how it could evolve under different COAs. The commander’s strategy would need to set priorities and allocate resources over the course of an operation or campaign that maximizes options for as long as possible, while also accomplishing objectives through multiple engagements and missions.

The technical needs for C3 capabilities that support Mosaic Warfare and advance DoD toward Wave 3 of mission integration will center on C2, given DoD’s ongoing investments in new communication systems and communication interoperability tools and gateways. Those requirements will be addressed in the following chapter.
DoD’s efforts to implement CJADC2 through service programs such as ABMS, IBCS, and CaaS are increasing the reach, interoperability, and resilience of DoD communications systems. As described in Chapter 3, improving the ability of the US military’s C3 architectures to support decision-centric warfare should focus on C2 tools that enable commanders to manage and expand their own decision space while reducing the optionality available to adversaries.

The technologies needed for C2 tools could be determined by assessing the requirements of decision support systems currently under development like the DARPA Adapting Cross-Domain Kill Chains (ACK), PROTEUS, or Complex Adaptive System Composition and Design Environment (CASCADE) programs. That approach, however, would only address the mechanics of developing COAs from a group of available forces under a prescribed set of conditions and assessing the implications for a commander’s current and future options.

A more sophisticated analysis is needed to evaluate the technical requirements for decision-centric C3. For example, a C2 tool or COA generation system would not necessarily enable the optionality needed to impose complexity on an adversary or create and sustain optionality for US forces. And although a
COA generation tool may help junior leaders execute mission command, the tool would also need to understand which units are in communication, their role in potential COAs, and configure networks to ensure the needed units are aligned with the appropriate commanders.

This chapter will develop a framework for assessing the technical needs for decision-centric C3 from different viewpoints as described in Figure 11 and detailed below. Technology requirements are assessed using multiple views to consider how the structure and functioning of C3 architectures are employed and would need to evolve.

**Stack View**
The stack model is often used to describe network technologies because it defines the architecture’s elements and how they interact to provide functions such as data transport or analysis. Common components of the stack view include the physical, network, information, and network layers, as shown in Figure 12. The elements needed in each of these layers for Wave 1 and Wave 2 of DoD mission integration are detailed below. From a C3 technology perspective, Wave 2 and Wave 3 of mission integration are largely the same, but the process DoD uses to define and develop forces would be more focused on building in adaptability and interoperability.

Like the Internet, decision-centric C3 architectures will need physical mediums for the movement of data; network structures to manage the movement of data between commanders, sensors, and effectors; information architectures to organize data into meaningful forms; and applications to assess information such as decision support tools. Current
technologies could support these needs, but would not enable the dynamic composition and recomposition of forces and networks in an adversarial environment while pursuing an optionality advantage.

**Physical**
Today, a lack of interoperability between networks and disparate systems constrains the compositability of US military forces. Software-defined radios (SDR) are addressing this limitation by enabling a more interoperable physical layer compared to analog radios by using multiple waveforms. However, SDRs are limited in the number of different waveforms they can employ by processing capacity and the need to pre-configure the radios for expected protocols. A more advanced solution like the GNU radio would use software-defined processing, which would allow an SDR to be reprogrammed dynamically to use new waveforms.47

**Network**
Different networks can be flexibly connected today using routers such as the Automated Digital Network System (ADNS) on ships or gateways such as the Battlefield Airborne Communication Node (BACN) on aircraft, but these systems need to be configured before use.48 A more advanced solution, as in the DARPA DYNAMO program, would combine and reconfigure networks in real time to address electromagnetic conditions, commander’s intent, and mission priorities.49

**Information**
The ability of a C3 architecture to translate data from sensors and other sources into useful information is improved through the increasing employment of open standards in data buses, but these standards are not universally applied. A more advanced solution would achieve interoperability using software toolkits,
such as STITCHES, that develop ad hoc communication chains between different message formats and waveforms to connect changing combinations of units as the force composes and recomposes.

Application

For most software architectures, application program interfaces (API) are published, allowing applications to be readily incorporated. However, the static nature of APIs requires applications to ask for or be pushed data they need, which limits the C3 architecture’s ability to dynamically reconfigure. A more advanced solution, like GraphQL for Internet APIs, would use an overarching structure that manages how and when applications are employed to implement COAs. For example, once a COA is selected, multiple APIs could be activated that align sensor information flows, reconfigure networks, and activate resupply planning.

Network View

As described in Chapter 2, command relationships in decision-centric warfare will follow communications availability under the approach of context-based C3. The same dynamic would hold true for other concepts under CJADC2 such as Distributed Maritime Operations or Multi-Domain Operations, as US military forces employ mission command to accommodate lost or degraded communications.50

Figure 13: A comparison of different network topologies

(A) Bounded system of agents or nodes (human/machine actors)

(B) Hierarchical structure: unidirectional power relations

(C) Network structure: interactions & links dominate agent characteristics (popular now)

(D) Heterarchical: combined hierarchical & network interactions

Figure 13 shows different network topologies and how they relate to C2 relationships. Although the bounded system of independent units in topology (A) using organic sensors and weapons would be resilient, its complexity is limited by the inability of units to exploit each other’s capabilities or coordinate their efforts to impose dilemmas on the enemy. A hierarchical structure like today’s military, shown in topology (B), would allow coordinated operations between units that could increase adaptability and complexity, but depends on communications with the commander, which makes the architecture fragile. The structure of topology (C) where “command” or the role of coordination falls to the highest-degree node, or hub, would be adaptable and would allow for coordination, but the hub may not be in a position to coordinate actions because it is not collocated with a commander having the authority and C2 tools to make and enact decisions.

Enabling optionality and implementing decision-centric warfare will require the ability to align C2 structures with available communications, rather than attempting to build a network that will survive in the face of concerted adversary jamming and physical attack. These needs lead to the hybrid architecture of topology (D) that combines the network approach with the hierarchical approach, which could be characterized as “heterarchical.” This topology would align command with the node having the highest degree among those occupied by a human operator and equipped with decision support capabilities.

The heterarchical network structure will require specific technologies. For example, it will need communication management systems that can identify units connected to each node, determine which node is likely to be in command, and the ability to route messages and throttle bandwidth in support of the commander and directed COAs. Heterarchical topologies will also require decision support tools distributed to each manned unit that could host a potential commander.

**Problem-Solving View**

The decision support tools used to integrate disaggregated forces and implement context-based C3 will need to do more than simply propose COAs that fulfill the commander’s objectives; they will need to enable optionality strategies by expanding the range of COAs possible using forces in communication with the commander and develop COAs that could narrow the options available to an adversary. An optionality advantage would likely be a critical contributor to imposing dilemmas that prevent the adversary from reaching objectives in time or in overwhelming the enemy’s centers of gravity.

Growing the number of options available to commanders will depend on rapidly assessing new situations, identifying viable COAs, and choosing those that keep the most options open. This approach contrasts with the problem-solving approaches commonly employed in project management, which focus on identifying one solution and efficiently aligning resources to pursue it. Deterministic project management methods are appropriate for situations in which most relevant factors are understood and there is likely a small number of effective COAs. They are not well-suited for situations involving great uncertainty, such as an adversarial military confrontation or new scientific developments. For example, at significant cost, the Manhattan Project pursued multiple approaches to increase the likelihood of successfully developing nuclear weapons. In these cases, the parallel assessment of multiple COAs is more appropriate.

One approach to assessing numerous options in parallel, shown in Figure 14, is evaluating problems solved in past operations, exercises, or simulations that are analogous to the one presented by the current scenario and operational objective. Using those solutions as a starting point, decision support tools would assess using simple models how available capabilities could be composed and operated to solve the new problem. To more rapidly seek out and assess similar situations, C2 systems could also use AI-based tools such as inference engines, multi-agent systems, or expert algorithms. In addition to enabling
more rapid assessment of a large number of options, analogous reasoning can make recommendations from AI-based decision support tools easier to explain compared to AI methods that rely on less transparent processes, such as deep learning.\textsuperscript{53}

The application of analogous reasoning to COA development would essentially be a form of supervised learning, because the historical, real, simulated, or exercise problems used as a baseline would have been previously reviewed and approved by a human commander. The AI algorithm would assess how the analogous solution could apply to the current situation and available forces. The models used to assess force packages and tactics could be deterministic to allow COAs to be compared directly, or stochastic if more options are desired and commanders are willing to set guidelines for a COA's minimum acceptable probability of success.

A problem-solving process using analogous reasoning could more quickly assess potential options than addressing each new situation from scratch, and the resulting increase in decision space could enable commanders to defer COAs that would constrain their options until the last possible moment. Moreover, if an AI-enabled algorithm is used to build COAs without the benefit of supervision, an adversary could influence the algorithm's learning through feints and probes that make the system believe COAs were successful that actually would have failed if not for the adversary's actions. The technology needs for emerging from the problem-solving view are summarized in Figure 15.

Nearly all the technologies needed to support analogous problem solving are software-based and will need to evolve over time. In addition to accommodating improvements to
algorithms and AI-enabled tools within them, decision support systems will need to incorporate new military capabilities or formations and digest a growing number and diversity of analogous situations for comparative analysis. The need for software-based tools and functions to continuously evolve makes them challenging to buy using traditional DoD acquisition and appropriation processes, which are designed to either purchase finished products or pay for time and materials, but not both. Recent changes to add a software-focused acquisition path and a software appropriations category that can be applied to procurement, R&D, or personnel spending will help address the ongoing nature of software development and operations but need to be more widely adopted across DoD.

**Time View**

Chapter 2 discussed the value of optionality and how the decision space available to a commander would change over the course of an operation. The concept of optionality, however, also applies to longer-term timescales, from strategy through tactical operation of the force. The capabilities of C3 architectures should help expand the decision space made possible by efforts across each timescale, as shown in Figure 16, rather than only during missions.

The longest timescale would be strategic. The priorities and objectives established by national and DoD leaders in strategic documents can expand or contract the decision space for subsequent force development and employment efforts.

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**Figure 15: Technological needs for problem-solving by analogy**

[Diagram showing the process of problem-solving by analogy with steps for problem analysis, specific objective, option management, implement solutions, and review results.]

Source: Report Authors
C3 architectures can impact the availability of strategies that expand the optionality available to commanders. For example, a heterarchical communications architecture that can support context-based C3 and mission command could enable a strategy that uses distributed forces postured forward to create uncertainty for an adversary, similar to the model directed in the DoD 2018 National Defense Strategy. 54

In the industrial timescale, capabilities could be developed that provide more interoperability and adaptability to future force packages. As noted above, requirements for new systems in a decision-centric or mosaic force would not be established through a deterministic engineering process but rather via stochastic assessment of the impact potential new capabilities would have in force packages across a range of future scenarios. To maximize the force’s optionality, decision-centric requirements would privilege systems that are highly recomposable and can sense or generate effects against many different adversary targets, even if they perform less well in some situations than systems optimized for those conditions. A C3 architecture can enable a larger number of potential systems to meet these criteria by incorporating features for information and network interoperability as described in the stack view above. In the Wave 3 implementation of mission integration, or Mosaic Warfare, the decision support tools used by operational commanders could provide the simulation environment for assessing the contribution of potential new systems.

The operational timescale centers on composition of forces in theater in preparation for a series of missions. As noted in Chapter 2, the Wave 2 instantiation of mission integration would enable force composition in theater, but new organizations and processes are needed for these activities, which are described in the organizational view below. Enhancing optionality at the...
operational level before missions will depend mostly on the composability of forces and C3 architectures. Additional options could be afforded if the adversary’s disposition and capabilities are better known, which could be achieved through probing or feints.

The tactical timescale is detailed in Chapter 2. The main factors to improve optionality during force employment are rapid COA assessment, composability, and an understanding of the adversary disposition and capabilities.

**Organizational View**

DoD’s C3 architectures do not exist in a vacuum. They must be employed by personnel in organizations through processes in each of the timescales described above. Optionality is key to gaining an advantage in decision-centric warfare, but simply fielding a more disaggregated force and decision support tools will only marginally increase the US military’s complexity and adaptability if the force can only be combined in a narrow set of ways. Decision-making organizations and processes will instead need to expand the option space available to commanders for as long as possible.

Today’s CCDR staffs lack people and tools to compose forces in a wide variety of configurations for upcoming missions. To enable composition of forces in the operational timescale, DoD could use an approach similar to that employed to compile computer programs from higher-level languages into code that can be executed by the computer’s processor. This approach

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**Figure 17: A graphical depiction of the mission compiler organizational construct**

Source: Report Authors
would start with a COA from a decision support system and then combine appropriate units to support the operation. Although force composition is primarily hardware-focused, it also entails the software composition of the force package in the information and network layers of the technology stack using STITCHES, SDRs, and network gateways.

The mission compiler construct could be used to inform needs for future missions. Although the compilation of units and capabilities into force packages in the operational timescale would be the organization’s main focus, as noted in Chapter 2, insights from this process could suggest opportunities for new capabilities that would improve the performance of force packages or enable greater optionality.

The Evolving Role of Information Processing in Conflict

The forces and mission systems that will be compiled by mission integration organizations increasingly derive their functionality from software, suggesting insights about mission integration could be gained from the evolution of information processing systems during the past several decades.

Early software development during the 1960s made little distinction between software and hardware, with engineers using the medium most appropriate to the specific task. However, hardware requires different capabilities and activities for design compared to manufacturing, whereas software design and production are basically the same activity, and replication costs are near zero.

Microsoft exploited the value chain asymmetry between hardware and software during the 1980s with its common Disk Operating System (DOS), which was made possible by IBM’s standardization of key interfaces like the Basic Input Output System (BIOS) and peripheral bus. Whereas the hardware for each personal computer had to be hand-assembled, the labor and cost of encoding additional floppy disks containing DOS software was very low. Although software design and production were largely simultaneous, the early PC era exemplified by DOS differentiated between resources associated with research and development and those associated with operations and sustainment. The Internet has enabled developers to merge software design with operations and continuously refine programs to meet user needs, integrating the personnel and funding devoted to development and sustainment. The resulting software-as-a-service (SaaS) model is used by several successful Silicon Valley technology businesses because it yields steady, predictable growth, can adapt to new security challenges and markets, and can be tailored to particular customer needs.

The continuous development model of SaaS depends on constant feedback from always-connected users performing actions around one business process, which is difficult to achieve for DoD missions given the intermittent nature of conflict. As described below, however, modern software development and acquisition models such as that used by Robotic Process Automation (RPA) can support DoD needs by merging the rapid feedback possible in SaaS with the tailoring possible by developing customized software.

An Example of a Mission-Centric Organization

The mission compiler concept suggests an organizational construct that could assemble forces for COAs as part of Wave 2 mission integration. In commercial enterprise information technology (IT) modernization, one trend that has emerged is use of RPA to bring efficiencies to legacy business processes such as inventory management, payroll, or document sharing without requiring a wholesale change of legacy enterprise IT systems.

RPA vendors develop core software products that work with the customer’s existing data management systems. The RPA program acts as a toolkit for automation, data sharing, and interoperability, similar to a macro that can be created in a software spreadsheet or word processing application. The toolkit can
allow functions like data pulls from different sources, copying data from one source into another, or filling out fields in one program using data from another. However, given the intricacies of legacy processes and systems, a customer can rarely implement and use RPA tools out of the box. Most RPA vendors, therefore, work with a forward implementation team, like a Best Buy Geek Squad, to install the RPA software on site. In this manner, RPA implementation mixes the core RPA automation toolkit with legacy IT systems, permitting customization and interoperability with the customer's overall software architecture and business processes.

The forward implementation team does not modify either the core RPA software product or the legacy IT system. Instead, they work to understand the set of underlying business processes to be automated in consultation with the user, and customize the RPA implementation accordingly. Using automated software generation in the toolkit, the RPA business can quickly build interfaces to the customer’s processes or enable the customer to unlock new functions. Figure 18 depicts the RPA model as it is employed commercially.

The RPA approach responds to the limitations that new software programs, even those based on open standards, experience integrating with existing software architectures and enterprise operations. Perhaps more importantly, the RPA process can assess if the enterprise IT system provides the added value desired by using the RPA toolkit, or if emergent behavior reveals new functionality or challenges for software developers to address.

Figure 18: Depiction of RPA model used in commercial settings

Source: Report Authors
The RPA model’s prevalence suggests business process automation programs like those for inventory or customer relations management often fall short of expectations if not accompanied by organizational and workflow adjustments to take best advantage of the automation. RPA businesses therefore frequently offer courses to acclimatize human users to the pending change and encourage trust and acceptance of the new technology.

To implement the Wave 2 version of mission integration, DoD could adapt an RPA-like model to compile forces into systems-of-systems that support the commander’s chosen COAs. In this model, CCDR users and the decision support or C2 system creates demands in the form of COAs, similar to the RPA process’ users. A mission integration cell staff, like the software vendor’s advance team staff in the RPA model, would configure networks and ensure interoperability between units called for by the COA using tools such as STITCHES and ABMS. The mission integration cell would also ensure movement of force elements called for in the COA to the operating area, apportion necessary logistics, and verify units’ proficiency for the intended operations.

The RPA model’s assessment of value added would help move DoD to Wave 3 of mission integration. As described in Chapter 2, decision support or C2 tools will evaluate performance of available capabilities in COAs that are possible in the current operational situation. The mission integration cell could extend this functionality to assess how modifications to existing systems or additional units that exist but are locally unavailable could...
improve the force’s performance in the same COAs or enable new COAs that expand the commander’s decision space. Using these insights, the mission integration cell could work with the Joint Staff to obtain needed platforms and formations from other CCDRs or engage DoD capability development organizations such as the Army or Air Force Rapid Capabilities Offices to quickly field modified or new capabilities that would enable improved performance or optionality.\[59\]

Over the longer term, the RPA model can enable Wave 3 of mission integration to influence the next generation of military capabilities. Using insights from assessing the performance of existing capabilities in possible COAs, mission integration cells could identify characteristics and attributes that may improve force-level performance in the future. Similar to the RPA team informing foundational improvements to enterprise program software, the mission integration cell could be employed as a partner in efforts by DoD to develop new capabilities, which may improve the speed and efficacy of force development efforts.

The RPA model for mission integration could have significant implications for DoD requirements, R&D, acquisition, and force management. Future reports in this series will explore these implications and the resulting organizational constructs.

**Summary**

DoD is already pursuing many of the technologies needed to implement C3 architectures able to support decision-centric warfare. As the stack view suggests, the physical, information, network, and application layers needed for establishing and sustaining C3 are in development or available, but will need to be accelerated using a coherent investment and management approach. The main technological shortfall in reaching a decision-centric C3 architecture is decision support applications that could enable heterarchical C2 structures and analogous problem-solving.

In parallel with fielding needed C3 technologies, DoD must explore and implement new organizational constructs and processes that can execute mission integration in theater. These institutional changes would also enable US military planners to harvest insights from mission integration to inform ongoing capability development efforts. Acting on these lessons, however, will require changes in how DoD defines requirements and advances new systems. Those changes will be addressed in a future report.
Since the Cold War ended, The US Department of Defense (DoD) has developed doctrine and capabilities predominantly for the most stressing campaigns it could face against opponents such as the People’s Republic of China (PRC), Russia, or North Korea. These worst-case scenarios are intended to ensure US forces can address “lesser-included” cases as well. This approach, however, favors concepts and systems designed for large-scale, high-intensity military conflict, and intelligent US adversaries are unlikely to present US forces with confrontations where DoD could leverage its strengths in missions such as power projection or precision strike.

To circumvent US military strengths, America’s rivals evolved approaches during the past decade, such as PRC and Russian gray-zone or hybrid operations, that obtain objectives at lower cost and escalation—albeit over longer timeframes—than traditional military combat. DoD should therefore revise its planning to raise the priority of new scenarios that stress the US military in different ways than theater-wide high-intensity combat such as through protraction, varying levels of escalation and scale, the use of proxy and paramilitary forces.

The People’s Liberation Army (PLA) concept of System Destruction Warfare and the Russian military’s New Generation Warfare are representative of the new approaches being employed against the United States and its allies. Although they are very different in their theory of victory and methodology, both

Photo Caption: A member of the US Army aircrew surveys the Norwegian countryside from the rear of a US Army Chinook helicopter during pre-exercise integration training on October 27, 2018 in Norway. Over 50,000 military personnel from 31 countries converged in central and eastern Norway for the NATO-led Exercise Trident Juncture 18. (Leon Neal/Getty Images)
concepts share a focus on information and decision-making as the main battlegrounds for future conflict. They direct attacks on an opponent’s battle network electronically and physically to degrade its ability to obtain accurate information while introducing false information that erodes the opponent’s ability to orient. Simultaneously, military and paramilitary forces would present dilemmas to the opponent by isolating or attacking targets in a manner that neutralized their combat potential and controlled the escalation of a conflict.

Decision-centric warfare will likely be a significant, if not predominant, form of future warfare. The US military will need to adopt new force designs and C2 processes to enable decision-centric warfare, but these efforts will come to naught if they are not combined with tools and organizations to fully exploit the optionality possible in a more disaggregated force operated using human command and machine control.

Current DoD efforts through CJADC2 and associated operational concepts to evolve US forces toward more distributed organizations and more disaggregated capabilities are an essential step to enable a more decision-centric approach to military operations. ABMS and several DARPA programs are developing C2 tools and processes that would increase the optionality available to commanders using these more distributed forces. However, neither DoD’s force design changes or C3 initiatives are sufficient for the US military to sustain an optionality advantage against peer adversaries that have already made the leap to decision-centric warfare and have a home field advantage from which to employ it.

The technical needs analysis above is only a first-order approximation of the changes required to move DoD from its current pursuit of Wave 1 of CJADC2 to the full Wave 3 implementation of Mosaic Warfare. Several programs are developing tools and systems needed to advance DoD’s C3 architectures and processes toward those required for decision-centric warfare. These programs will need to be continued and joined by new initiatives to enable Mosaic Warfare.

More importantly, however, new organizations and processes will be needed that allow CCDRs to compose and integrate disaggregated forces in theater and change the way DoD defines requirements and develops new capabilities. Without dramatic reforms to DoD’s requirements and force development processes, the US military risks falling behind adversaries in the competition for decision-making advantage, thereby threatening its ability to protect US interests and allies against great power aggression.
IMPLEMENTING DECISION-CENTRIC WARFARE: ELEVATING COMMAND AND CONTROL TO GAIN AN OPTIONALITY ADVANTAGE

ENDNOTES


10 These benefits are detailed in Bryan Clark, Dan Patt, and Harrison Schramm, Mosaic Warfare: Exploiting Artificial Intelligence and Autonomous Systems to Implement Decision-Centric Operations.


This subject is treated in more detail in Ross Pigeau and Carol McCann, “Reconceptualizing Command and Control,” Canadian Military Journal, Spring 2002, pp.53-55.


Given the CCP’s high degree of confidence in its ability to employ calibrated levels of force to achieve objectives, the proposed approach could aim to directly challenge the establishment of CCP conflict initiation criteria. Specifically challenging the PLA’s systems destruction approach to warfare, the missile force’s optionality could decrease the PLA’s level of understanding of the design of US operational systems and increase the range of potential outcomes in PLA systems confrontation assessments. If the PLA is not confident it would achieve its objectives in a conflict given the uncertainty imposed by the missile force, the CCP may refrain from initiating a conflict. See Jeff Engstrom, Systems Confrontation and System Destruction Warfare (Santa Monica, CA: RAND, 2018), https://www.rand.org/pubs/research_reports/RR1708.html.

Two examples are the delayed German offensive in the Ardennes forest in 1940 at the beginning of the Second World War and the sub-optimal Allied counter-attack in the same forest during 1944’s Battle of the Bulge. In both cases, the poor road network and a lack of suitable platforms to carry logistics and fires delayed or constrained the maneuver force’s ability to use speed and scale to impose dilemmas on the opponent. See Martin Van Creveld, Airpower and Maneuver Warfare (Montgomery, AL: US Air University, 1994), https://apps.dtic.mil/dtic/tr/fulltext/u2/a421685.pdf.


US Joint Staff, “Charter of The Joint Requirements Oversight Council (JROC) and Implementation of The Joint Capabilities


