Future Command and Control: Closing the Knowledge Gaps

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Future operating environments will require a real time, fully networked command and control (C2) capability; this concept is considered a critical enabler throughout the Department of Defense (DOD), regardless of advocacy for platform compositions or force structure designs. The Air Force Warfighting Integration Capability (AFWIC) identifies C2 as the required core capability to conduct Joint multidomain operations across all types of conflicts.[1] This concept, which calls for a comprehensive sensing grid, has been validated by results from the Futures Wargame and numerous exercises. The vision is highly aspirational but deemed vital for the future operating environment. Contrary to what many advocates of this technology claim, human decision-making decreases in quality as access to information increases, unless human decision-makers have relevant training and knowledge about the environment. The Air Force must consider some immediate implications for organizational strategy and funding to eventually achieve the long-term vision for a future C2 capability.

Definitions

The Joint definition of command and control includes two elements: the authority over forces and the integration and synchronization of actions.[2] This article focuses on the latter element as technology will continue to shape how the military integrates and synchronizes. The Air Force must be prepared organizationally to address this aspect. Technology will continue to compress C2 structures by providing commanders with direct access to lower echelons. While this is an important issue that will continue to create complications from the authority aspect, this article focuses on the closer issue of whether C2 integration and synchronization can even be developed for the future operating environment.

This article adheres to the simple label "C2" with the understanding that any relevant C2 capability in the future will operate within and through every domain—air, land, sea, cyber, and space—by a Joint crossfunctional force. This concept represents any service- or career-field-specific terms such as multidomain C2 or Joint all-domain C2, as they share the same key characteristics. This

comprehensive future concept of C2 includes a significant transition from a platform-centric to a platform-agnostic capability.

The timeline for a future capability varies depending on context. For conceptualization of capabilities and operational environments, the future is often represented by more than 15 years from the present. This long-term perspective provides guidance for desired end states and will be referenced within this article as the AFWIC's future vision. The Air Force examines operating concepts in windows 5-15 years out.[3] This midterm future is critical for technology developers as it provides a realistic timeframe for funding and implementing projects that advance the Air Force toward its long-term vision. The short-term future, less than five years out, is generally already programmed, thus the midrange period is the focus of this article. Currently, the long-term aspirational vision provides sufficient guidance to drive technology development, but as an organization, the Air Force has not yet committed to the necessary incremental steps to achieve this vision.

Some conceptual visions jump straight to fully autonomous decision-making, but that is premature for the midterm timeline of a C2 operating concept. There are three tiers of autonomy: (1) semiautonomous, or human-in-the-loop operations where human action is necessary to continue functioning; (2) supervised autonomous, or human-on-the-loop operations where a human observes and can intervene if desired; and (3) fully autonomous or human-out-of-the-loop operations without any human feedback or communication.[4]

All three tiers fit within the Air Force's doctrinal concept of C2.[5] While eventual artificial intelligence (AI) applications should be kept in mind, a future C2 capability will have humans in the loop, or at least on the loop, for initial spirals.

Background

The Joint Operating Environment 2035 depicts an extremely complex and interactive future environment.[6] The Joint Force requires a C2 capability that can operate within such an environment while maintaining its necessary functions as a critical enabler.[7] Across the spectrum, from conventional warfare to competition below the level of armed conflict, C2 is a necessary component in a complex future. The AFWIC's response envisions strategic dominance through a persistent distributed networked C2 capability that enables global multidomain operations "within seconds and minutes."[8]

This persistent network requires the proliferation of sensing and communications hardware. The early development of such hardware is promising. The Air Force is moving toward its goal of a proliferated geosynchronous and low-earth-orbit integrated architecture with small, persistent satellites from the military

sector through the Air Force Research Laboratory (AFRL) Space Vehicles Directorate (AFRL/RV) and from the civilian sector through commercial partnerships.[9] The proliferation of intelligence, surveillance, and reconnaissance platforms continues to increase alongside operational capabilities that transform the everyday war fighter into a sensor. From an enterprise perspective, the Air Force acquisitions process is emphasizing interoperability with modular components and open-source programming. The initial development of hardware for a proliferated network appears to be on pace.

From a software perspective, the AFRL Sensors Directorate (AFRL/RY) is researching what information and processes will be necessary for implementing real-time distributed coordination across such a large system.[10] Their contributions will help determine the feasibility of the cognitive process for both human-in-the-loop and human-on-the-loop operations while achieving the appropriate workload division for aggregated sensing and data processing. This software and analytics research is critical for the development of a C2 capability, but the timeline for expected results is uncertain. The AFRL/RY is also researching data processing within a trust and mission-assurance context, but that effort is outside the scope of this project.

How well human war fighters and decision-makers will utilize these technologies is not so clear. Empirical evidence suggests more information often has negative effects on decision-making, resulting in inferior outcomes. Humans make poorer or incorrect decisions, compared to what they value, with increasing amounts of information.[11] It follows, then, that unfamiliarity and ambiguousness make Air Force officers worse strategic decision-makers.[12] To prevent information overload, humans employ heuristics to limit the required amount of information processing.[13] Dealing with massive amounts of information will not necessarily make it more difficult or time-consuming for humans to make decisions, but it is more likely that humans will not identify some crucial information, resulting in dysfunctional or less optimal outcomes.[14] The problem becomes even more difficult as humans interface with an increasingly large number of nodes.[15] The processing speed and capacity of systems are quickly improving, but the human interaction effort is still the key problem for improving a human-tech interface.

The vision for a networked C2 capability that enables Joint operations in a complex and information-rich environment is highly aspirational. If the Air Force assumes new technology can transition directly into real-time, distributed C2 without accounting for known issues of information veracity, task saturation, and analysis paralysis, it will never achieve its vision. Operators, decision-makers, and networked systems must be supported by appropriate organizations

and procedures to realize desired effects. The Air Force has clearly established the requirement for this future C2 capability, but will they be prepared to use this capability when it becomes available? What incremental steps must the Air Force take in the next 5-15 years to enable the development and implementation of this capability? Is the Air Force on the right track?

Knowledge Gaps

The organizational processes for training and implementation are vital to a successful spiral development process. The desired end state is not yet defined enough to develop tactics and procedures for future war fighting, but it provides guidance on the general direction for technological development. The next few incremental steps for how the Air Force prepares to organize, train, and equip for this future C2 capability are where the most problematic knowledge gaps still exist.

Challenges and Implications

The intended purpose of a future C2 capability is quicker and better decision-making from the tactical to strategic levels of warfare and policymaking. Even though the concept of turning massive amounts of data into usable information seems intuitive, more data does not necessarily provide a better context for understanding an operating environment or anticipating outcomes to alternative courses of action. In fact, the most likely scenario is that more information will produce worse decisions. New technology, alone, will not provide a comprehensive solution for C2 in a complex operating environment.

An appealing assumption is that a sufficiently advanced technical interface with a data-fused backend will provide decision-makers with an intuitive, decisive aid for making real-time decisions. Unfortunately, that assumption fails to hold up in real-world practice. If a decision-maker is not adequately trained or knowledgeable about the information presented on a system, decision accuracy and quality can decrease within an environment of better information.[16]

The solution cannot be one-sided where technology is developed for humans to use. It must be double-sided where technology is developed alongside training that educates humans to work in an information-centric environment. Even when humans are only on-the-loop and not directly in the C2 process, humans will be required to interact with more information at a faster rate than ever before. To realize this vision of improved decision-making with a networked C2 capability, the Air Force must deliberately and iteratively develop training and build knowledge for the systems and their operating environments.

Fortunately, this problem is not entirely unknown within the Air Force. Multiple organizations have nascent efforts to understand or address elements of the problem. Together these efforts are creating an initial foundation, but they are not yet fully synchronized across organizations or able to assume any organizational staying power in the next few years. The Air Force must consider three major implications in the short term to realize the future vision for C2. Each of these implications is discussed in detail below, but all fall under the broad theme that new technology alone will not enable future C2 without a deliberate effort from the Air Force to organize, train, and equip for this capability throughout its entire development process.

Capability as a Catalyst

The successful adaptation of new operating concepts cannot be forced from the top down. To truly be disruptive, a new technology or capability must act as a catalyst by enabling war fighters to employ fundamentally different approaches to how they operate at all levels of warfare. This tactic may be challenging in an era of low-level, irregular, and proxy warfare as it is difficult for new technologies to prove anything without being used in a major war. Without stark success in application, new technologies are normally assimilated into old doctrine rather than stimulating the desired changes.[17] Even when developed and used appropriately, military organizations have a history of misperceiving benefits or failing to integrate technology properly.[18] If a future C2 capability is not identified by war fighters and decision-makers as essential to survival or success in future conflicts, it will be extremely challenging to integrate the capability into military doctrine or organizations, even if it is successfully developed.

Another adaptation hurdle is whether strategic planning creates temporal mismatches between the requirements of today versus a long-term future. At their worst, strategic visions can turn a desired operating concept, such as the AFWIC's vision for a future C2 capability, into a programmatic demand signal. This development may hinder innovative developments or fenced-off budget investments to ensure consistency with previous justifications.[19] Demand signals for a future C2 capability must not be replaced by programmatic funding signals for specific enabling programs. The C2 requirements the DOD established for the future operating environment must remain the overarching demand signal.

Throughout military history, the pace of a capability's development has been chiefly determined by the extent to which its mission and operational function are known and defined.[20] Even if the potential of an innovative technology is readily apparent, its initial success in tests and application is not inevitable. This separation often comes from an inability to fit the capability within current

tactics, techniques, and procedures rather than embracing the unknown change that might result.[21] But even having an established doctrine is insufficient if the Air Force is not organized to support an innovative capability.[22] The Air Force recently formed a multidomain warfare officer career field to lead operational-level C2. In establishing this career field, the Air Force solicited a broad range of experience and expertise from other career fields,[23] providing an excellent environment for innovative perspectives as the future C2 capability is developed. Common training in this career field provides foundational knowledge, but it remains to be seen whether this specialty limits itself to today's procedures and doctrine or if it permits the capability to act as a catalyst for how war fighters operate in the future.

The Air Force is aware that implementing this new C2 capability necessitates information superiority, but organizational parochialism could easily prevent war fighters from developing approaches for war fighting. To achieve the future vision, C2 must be "agnostic to domain, platform, and service."[24] This shift threatens the Air Force's institutional identity, founded on fielding the most technologically advanced platforms.[25] It is not clear if the Air Force is simply echoing Joint language or if it is prepared for the corresponding shift away from a platform-centric concept of air superiority. Operational concepts that rely on traditional air superiority against technologically capable adversaries are already futile.[26] The growing demand for information superiority has simply been added to the existing operating concept's reliance on air and space superiority, demanding an insatiable requirement for all-domain dominance that is simply not feasible—at least not in a strategically relevant timeframe.[27]

Information has become one of the seven Joint functions, alongside C2, and is recognized as necessary for enabling effective decision-making.[28] It is yet to be determined how the formation of the Space Force within the Department of the Air Force affects this institutional identity, but integration between the Air Force and the Space Force through the information Joint function will be strategically imperative and must not be inhibited by service parochialism. The creation of a new career field and an additional service within the department have created an environment where war fighters can develop new tactics and approaches that fundamentally change how we fight and win wars with information. This environment is ripe for a disruptive catalyst like a future C2 capability, as long as the individual services allow war fighters to develop the capability freely and do not attempt to force adaptation within current doctrines.

Deliberate Human Integration

The DOD recognizes information superiority in the future hinges on systems integration rather than just individual technologies.[29] But while it focuses on the role that technology plays in developing these systems architectures, the Department largely disregards the human integration piece. Wargames incorporate tiers of automation and analytics in future environments without articulating the role of human interaction.[30]

To conduct decision-making at the "speed of relevance," the DOD's vision of C2 requires the capability to "connect, share, and visualize" information across all domains at all levels of warfare.[31] How, or even if, this can be accomplished is a still unanswered question. Enabling technologies that utilize novel information and computing techniques might provide improvements beyond what is possible today, but they will never provide a comprehensive solution that does not require human integration. Enablers, such as AI, machine learning, or cloud computing are still enablers, not decision-makers. Air Force leaders often refer to these technologies as if the technology itself is what will provide a future C2 capability.[32] The Air Force advocates for technological speed and automation without calling for an equal focus on human integration, even though it recognizes the human integration aspect is vital for future effectiveness.[33] These arguments may be necessary to advocate for program funding, but if the Air Force relies on this approach, amazing technology might just sit on the shelf.

Having identified the need for deliberate human integration, the AFRL Airman Systems Directorate within the 711th Human Performance Wing (AFRL/RH) has three main areas of research specifically targeted at this element of a future C2 capability: distributed team performance, human-machine teaming, and training.[34] All three areas are vital for understanding and deliberately developing human integration. The AFRL/RH has identified multiple research streams in each area for initial spiral efforts over the next 5-15 years, but these nascent efforts have yet to gain significant traction within the larger science and technology community or from the AFWIC.[35] The AFRL/RH has established initial proposals and testbeds, but more funding for formal programs is necessary to synchronize these cognitive integration efforts alongside the technology-focused programs.

More developed from the programmatic side is the advanced battle management system (ABMS). The concept for the ABMS essentially expands C2 beyond an individual platform into a comprehensive networked capability with built-in data fusion and decision processes. The problems and delays this program has already encountered early in its development showcase how difficult it is to

develop a capability for a long-term vision without clear guidance for a spiral process. Regardless of whether the ABMS retains its nomenclature or another concept develops for C2, the future operating environment requires an enabling capability that generates, shares, and processes massive amounts of information for decision-makers. To provide an informative common operating picture, a future C2 capability must operationalize data fusion and the prioritization of information successfully. ABMS advocates will continue to argue it provides the answer to C2, but as we saw earlier, human decision-makers are only as good as their training and familiarity with using technological aids.

The Air Force must accept the responsibility for deliberate human integration at an organizational level and direct the training and development of such activities among appropriate stakeholders. The AFRL has recognized the need for deliberate integration of human training and knowledge, but their research proposals have not yet captured the necessary buy-in and funding from the larger Air Force. The ABMS is receiving the necessary programming to continue development, and human integration must be considered early and developed deliberately alongside the technologies. Yet it is often touted as a replacement rather than an integrator for human decision-making, and the Air Force has not coordinated the larger effort that directs the necessary human integration for a future C2 capability.

Iterative Concept Development and Funding

No program or technological advancement can single-handedly provide a panacea for future C2 requirements. It is tempting to believe a single program or effort can bridge the gap from where the Air Force is today to where it needs to be in the future. But a future C2 capability will require numerous iterations of concept development, each significant within their own right, and corresponding iterations of program funding. This requirement will be particularly challenging for such a large-scale C2 capability because prioritization and funding need to be committed in the short term for efforts that cannot yet promise the desired end state. A significant gap exists between current DOD funding and the aspirational vision for C2. The Air Force faces a lengthy development process, and organizations such as the AFRL and the AFWIC will be required to produce multiple iterations of technical advancement and incremental integration to realize the final vision.

While the AFRL is structured to advance scientific research, it is not well-structured to directly develop war-fighting capabilities.[36] Programs that integrate across science and technology lanes early to develop new operational concepts are high risk but necessary for innovative capabilities.[37] Both the AFRL and the

AFWIC have put forth initiatives to establish experimentation events to provide an environment for incremental development and implementation.[38] Recent planning for wargames, such as the Futures and Doolittle games, also emphasizes the need for spiral feedback.

These interactions are instrumental for concept development, and they must be protected. Shared participation may help coordinate internal planning and budgeting activities,[39] but the Air Force must accept the ambiguity of early concept development and protect these high-risk environments, even if a decade of experimentation fails to provide a program capable of producing the final vision in a single budget cycle.

The Air Force and DOD visions for future C2 continue to evolve; this instability can slow down the early programming for scientific research and investment.[40] The AFRL has pushed forward with internal guidance for kickstarting and directing more research on human-centric C2.[41] Even though the demand signal will likely continue to evolve, the AFRL must continue to move forward with incremental efforts.

Investment in a future capability demands balancing the budget between new technologies and legacy systems. The Air Force is underinvesting in the former and overinvesting in the latter; this prevents the long-term development of transformational technologies.[42] Unfortunately, the Air Force has not been able to demonstrate much success with prototype-based spiral development for large programs.[43]

Redirecting funding and effort toward new programs in the hope of finding shortcuts to the final vision slows down necessary progress. The AFWIC's operating concept and force designs provide the strategic vision, but the entire linkage from concept to planning and funding through implementation must be deliberate for a C2 capability that is so fundamentally different from how C2 is executed today.

The commercial sector is often leveraged as a way to attain technological advancement quicker or cheaper than it would be to develop such advancement through organic DOD processes, but this solution fails to overcome the issues that the Air Force would face with a future C2 capability.

Commercial off-the-shelf products can be used by war fighters to identify potential ways technology can be used to develop new capabilities. That is, if the Air Force as an organization can still permit the capability to act as a catalyst in how war fighters develop new approaches rather than forcing adaptation within current tactics and doctrine. Otherwise, commercial products are simply inefficiently or not used in place of existing means. The commercial sector is also facing the same problems as the DOD with developing human integration within

its products and capabilities. Commercially sourced or collaborative efforts might provide quicker or easier access to training that could enable the necessary human integration piece.

But even if these efforts are successful at training and building organizational knowledge of the capability and its environment, the Air Force must still implement the corresponding organizational changes. Without lasting changes that direct ownership and continue to deliberately develop the human integration piece, any advancements in an Air Force capability will not be maintained.

The commercial sector is spiraling with incremental concept development and funding, as well. Commercial products or services are not able to achieve the final vision in a single step.

The Air Force must be able to plan and fight wars organically with a future C2 capability; it cannot rely solely on a contractual arrangement with the commercial sector. All three of these implications for developing a future C2 capability still apply whether it is a wholly Air Force effort, an Air Force-commercial collaboration, or a fully joint-commercial effort.

Conclusion

This effort scoped the implications for the Air Force's way forward. These challenges must be met first and soon, but once the Air Force has closed these knowledge gaps, it must address the larger issue of how the Air Force's concept of a future C2 capability fits within the larger Joint framework—something upon which the Joint community has different perspectives. Regarding the nature of a future C2 capability, the Air Force perspective focuses on enabling global effects whereas an Army perspective originates from the principle of maneuver; future C2 often implies something different between services. Regarding responsibility and authority, some staffs place a future C2 capability within the purview of current and future operations whereas others place it within the communications and information realm; future C2 implies something different between Joint functional areas. Joint integration of the acquisition process will also significantly affect the development process. There is an explicit requirement for Joint operations with a future C2 capability, but the Joint community does not yet share the same perspective. How the Air Force's way forward fits within the larger Joint framework will develop as a question for future research.

The DOD has established the requirement for a real-time networked C2 capability for decision-makers to operate successfully in the future operating environment. This is not a call to change what the Air Force is doing; it is a call to protect what it is doing right. Both the AFRL and AFWIC have nascent yet promising efforts to develop a future C2 capability, but knowledge gaps on how

to continue these efforts persist. This article outlined three implications the Air Force must consider and resolve in the short term for the aspirational vision of future C2 to eventually become a reality. First, the capability must act as a catalyst to drive transformational change; it cannot be forced. Second, technology alone cannot provide the capability; transition requires deliberate human integration. Third, the Air Force as an organization must embrace iterative concept development and funding, even as this advocacy will struggle against shorter-term or more tangible priorities.⊛

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