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RESILIENT MULTI-DOMAIN COMMAND AND CONTROL:
ENABLING SOLUTIONS FOR 2025 WITH VIRTUAL REALITY

by

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Biography

Mr. Doug Fullingim is temporarily assigned to the Air War College, Air University, Maxwell AFB, AL, from the Air Staff A9 Studies, Analyses and Assessments Directorate, where he is the Technical Director for the Analyses Foundations and Integration Directorate. Mr. Fullingim's work has included operational analysis of USAF force structure recommendations, weapon system survivability, and mission risk, leveraging high-power computing environments. He has extensive test and evaluation experience, including C4ISR systems, space systems, weapon systems, and testing electronic warfare systems in actual operational environments. He is a graduate of the USAF Academy (BS, Astronautical Engineering), Air Force Institute of Technology (MS, Systems Engineering), and University of New Mexico (MBA). He has been a USAF civilian, US Army civilian, and a USAF officer over his 30 years of government employment.

Abstract

The emerging threat environment in 2025 and later is challenging for forward operating positions in theater. The emergence of survivable, long-range, precision weapons in the air, space, and cyber domains puts previously remote, monolithic, command and control (C2) sites, such as the theater Air Operation Centers (AOC), at risk. The Multi-Domain Command and Control (MDC2) concept's Multi-Domain Operation Center (MDOC) offers structural changes that could improve resilience, but is not planned for implementation until 2035. Emerging commercial virtual reality (VR) systems could distribute many AOC functions now, and accelerate the transition to the MDOC structure such that resilience could be increased against the 2025 threat. Distributed, collaborative VR technologies, leveraging emerging commercial capabilities, and supporting technologies are identified and discussed for each of these product types. Spinoffs supporting tactical C2 are pointed out, but not covered in this paper. Considerations for training and acquisition are highlighted. Recommendations include technology demonstrations in the AOC framework, and inclusion of distributed VR in the MDC2 experimentation campaign, and continued interaction with the game development industry.

Introduction

Background

This paper is being prepared in response to the USAF Chief of Staff's Strategic Studies Group's topic for the Air War College Airpower Vistas 2017 elective class. The topic asked for this group to address the question:

Detail the scope of threats in the 2025 timeframe to forward operating bases and operating locations in the four defense planning scenarios that span the combatant commands. How should the Air Force respond to these threats, considering the use of new and existing weapons and concepts, to ensure our ability to command, control and execute air operations in these future scenarios. Consider both existing air-to-surface and surface-to-surface threats as well emerging technology threats to include drones and directed energy in the analysis.¹

This paper addresses the topic by examining the application of virtual reality technologies to the command and control of airpower, and how such technology could be leveraged to increase resiliency of at-risk facilities across the combatant commands. The primary focus is on the Air Operation Center and its successor, the Multi-Domain Operation Center, but additional applications will be highlighted as they arise.

Thesis

Command and control (C2) can be made more resilient in 2025 by leveraging emerging synthetic environment technologies, e.g. virtual reality, to accelerate transition from the Air Operation Center (AOC) to the Multi-Domain Operation Center (MDOC), which is designed to be inherently more resilient, but is slated for operation in the 2035 timeline.

Definitions

The reader needs to have an understanding of several key terms and concepts relating to command and control doctrine, the proposed multi-domain command and control concept of operations, and synthetic environment (e.g. virtual reality) technologies. This, necessarily lengthy, section of the paper provides information in support of developing that understanding. It begins with a discussion of existing air power command and control implementation, follows with an explanation of key multi-domain command and control concepts, and then defines terminology necessary for understanding synthetic environment technologies. Readers familiar with these concepts should proceed to the methodology section.

Command and Control Doctrine

Joint Doctrine

Joint Pub 3-30 describes the Command and Control of Airpower from a joint doctrinal viewpoint, and establishes the Joint Force Air Component Commander (JFACC) as the focal point for air operations. Designation of the JFACC is at the discretion of the Joint Force Commander (JFC), and is usually based on which service component provides the preponderance of the airpower and has the ability to provide necessary command and control.² The JFACC is responsible for six primary tasks: preparation of the Joint Air Operations Plan (JAOP), recommendations to the JFC for apportionment priorities of air assets, allocation and tasking of air forces based on the apportionment decision, production of an Air Operations Directive (AOD) from the JFC guidance for use in the development and execution of the Air Tasking Order (ATO), provision of oversight and guidance during execution, and assessment of the results of operations in support of JFC assessment activities.³ The JFC may task the JFACC with additional requirements, depending on where he places air defense, airspace control, and space coordination authorities.⁴

The Joint Operational Planning Process for Air (JOPPA) is used to create the top level guidance for the employment of airpower.⁵ It is derivative of the Joint Operational Planning Process (JOPP) described in *Joint Pub 5-0*. Figure 1 comes from JP 3-30, and illustrates the joint air operation planning process and products.⁶

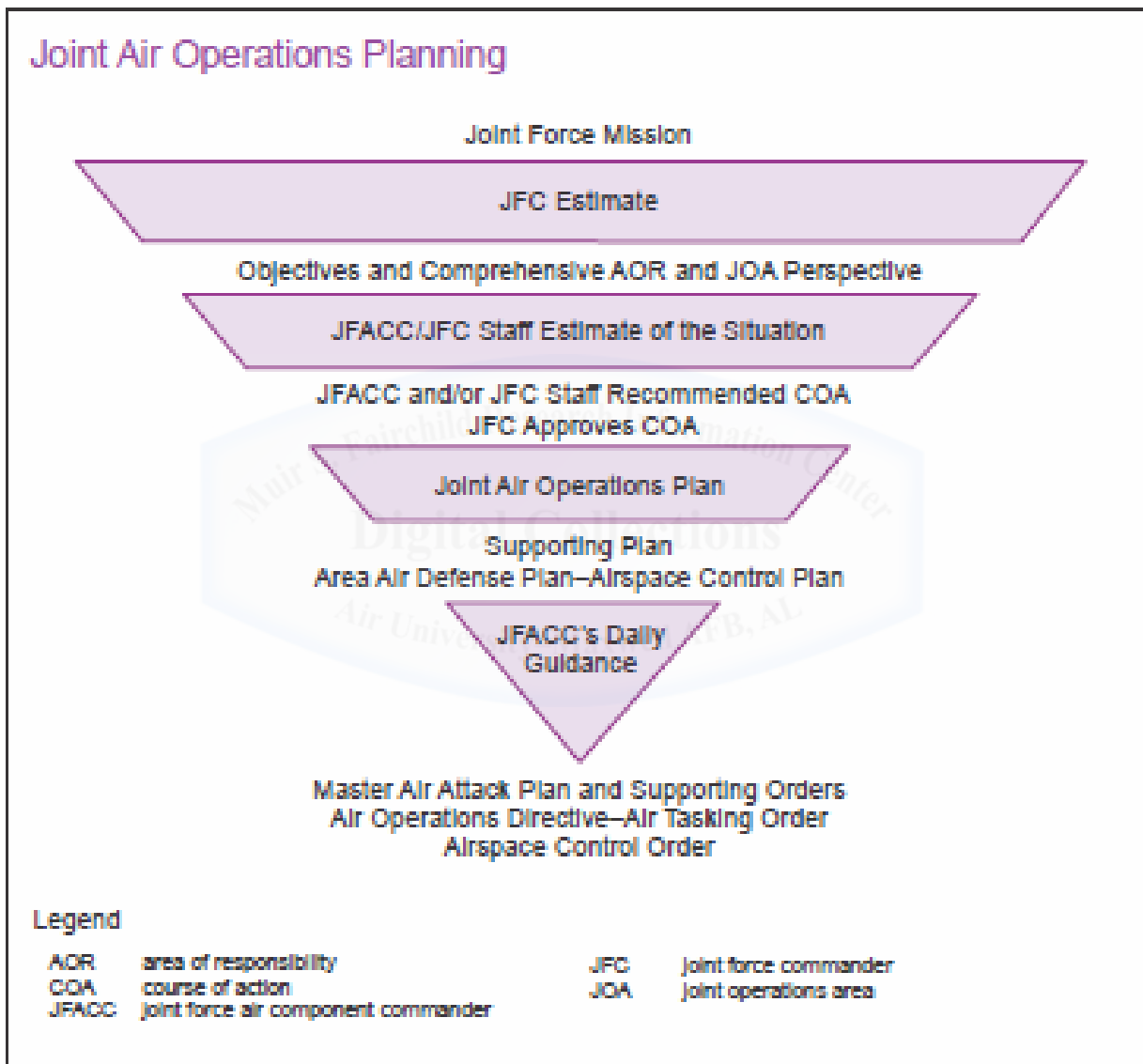


Figure 1. Joint Air Operations Planning (reprinted from *Joint Pub 3-30*)

This joint air operations planning process is resource intensive. JP 3-30 provides a list of specialists that might contribute to the effort. It is provided as figure 2.⁷ This will become

important later, when the size and complexity of the modern air operation center are discussed.

Given the outputs of the JAOP process and the capabilities shown above, the JFACC can begin the set of tasks more typically associated with the AOC.

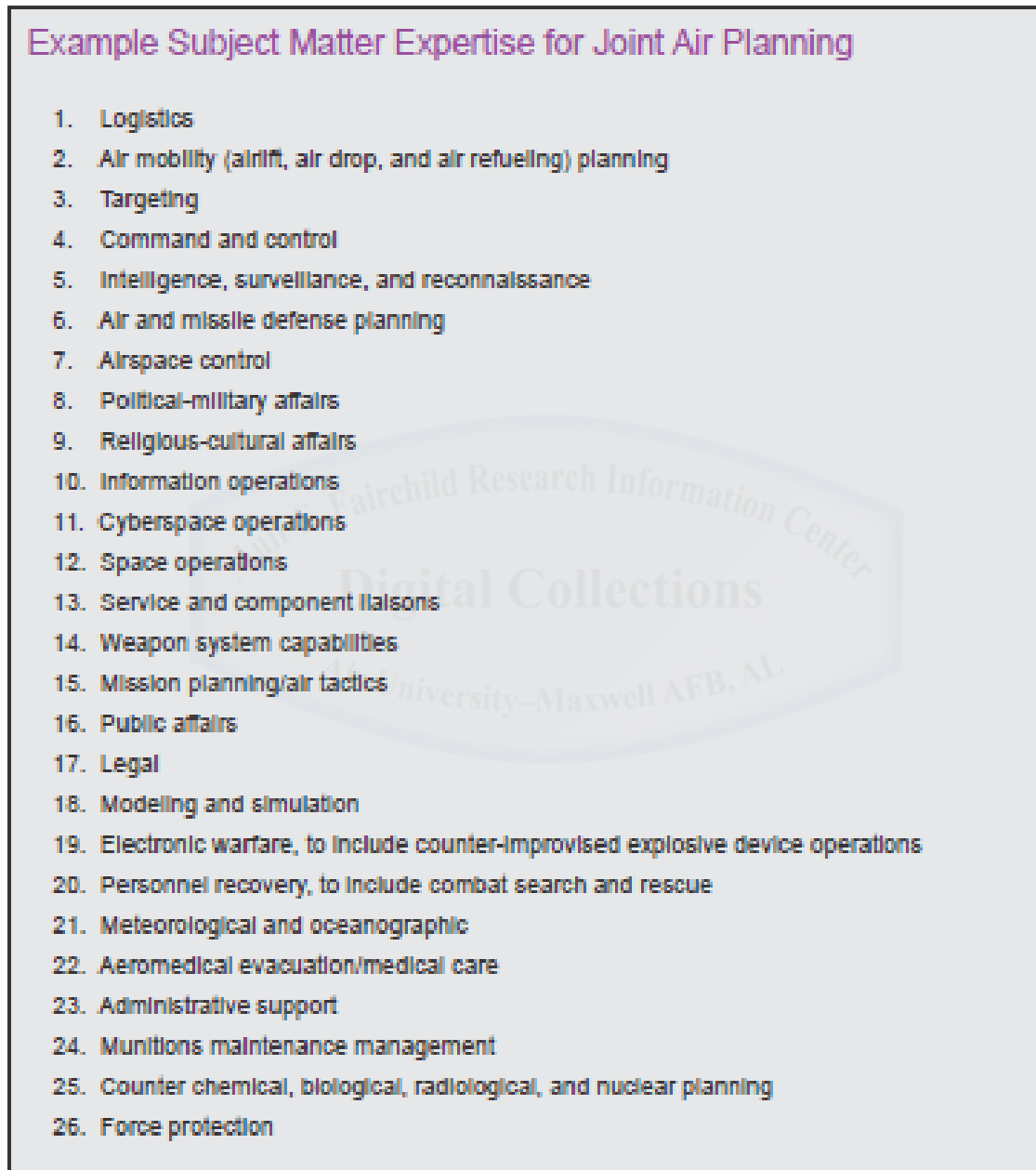


Figure 2. Example SME Requirements (reprinted from *Joint Pub 3-30*)

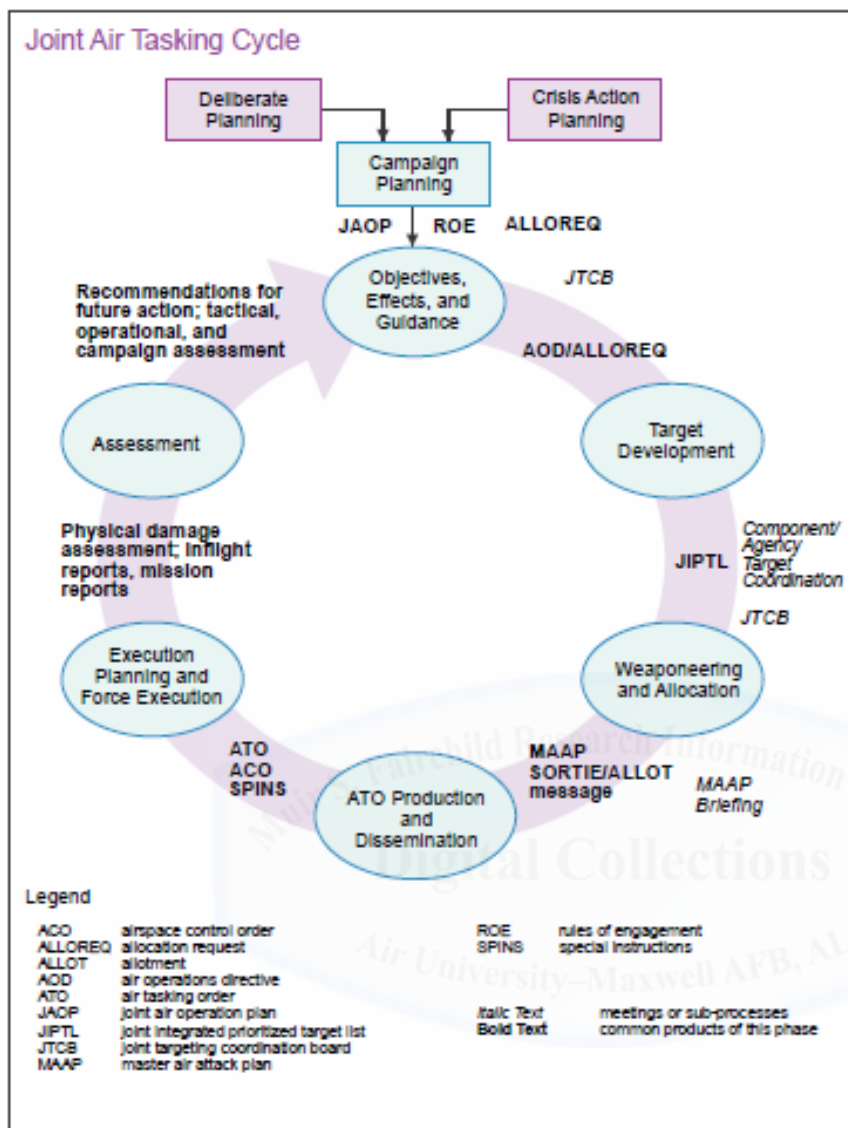


Figure 3. Joint Air Tasking Cycle (reprinted from *Joint Pub 3-30*)

The Joint Air Tasking Cycle is the series of actions that implement the results of the Joint Air Operations Planning process. Figure 3 captures that process from the joint doctrinal perspective.⁸ Starting with the outcome of the JAOP process, consisting of the AOD and other planning guidance, the process develops a prioritized target list, evaluates targets and methods for achieving desired effects, culminating in a master air attack plan (MAAP). This plan informs the ATO, ACO, and SPINS. Tactical planning and execution follows, with the AOC providing oversight and monitoring. Post-execution, the AOC provides an assessment and

recommendations for the next iteration of the cycle. This cycle continues until the military objectives are achieved or operations are terminated. It is typical for the Air Force to provide the JFACC, so an understanding of relevant Air Force doctrine will be discussed next.

AF Doctrine

Under Air Force doctrine, the Air Operation Center's tasks are taken from *Annex 3-30*, which defines Air Force Doctrine for Command and Control, and are summarized here to capture the current AOC construct. First, it develops the component strategy and requisite planning products. Second, it performs the task, execute, and assess cycle for the component. Third, it plans and executes the intelligence, surveillance, and reconnaissance tasks in support of assigned missions. Finally, it conducts operational assessments to measure progress toward achieving operational objectives.⁹ This is a slightly different formulation than the description in joint doctrine, with some of the explicit JFACC tasks rolled up into more general guidance. As in joint doctrine, the AOC may accomplish other tasks, if the combatant commander chooses to assign them to the JFACC. In that case it may also integrate and coordinate theater air mobility requirements, develop and issue airspace control procedures, and manage air and missile defense, cyber defense and space defense for the combatant commander.¹⁰ Doctrine specifies five divisions that accomplish these AOC tasks. They are: strategy; combat plans; combat operations; intelligence, surveillance and reconnaissance; and air mobility.¹¹ The details of AOC operations are captured in *AFI 13-1AOC, Volume 3*.

The Strategy Division is primarily responsible for developing strategy and planning products. *Annex 3-30* lists four teams that comprise the strategy division. They are the strategy plans team, the strategy guidance team, the operational assessment team, and the information operations team. They produce the Air Operations Plan and the Air Operations Directive. They

also run the assessment process and generate other COMAFFOR guidance as required.¹² Their processes involve creative and critical thinking to transform higher headquarters guidance, operational art, subject matter expertise, and an appreciation of the current state of the theater into planning guidance for the operational and tactical airpower planners.

The Combat Plans Division translates the outputs from the Strategy Division to produce the plans and orders that accomplish the air component's assigned missions. The doctrinal standard calls for four teams. The Targeting Effects Team (TET), Master Air Attack Plan (MAAP) Team, Air Tasking Order Production Team, and the Command and Control Planning Team.¹³ Combat Plans produces the Area Air Defense Plan (AADP), Air Tasking Order (ATO), Airspace Control Order (ACO), Special Instructions (SPINS), and the air component inputs to the Joint Integrated Priority Target List (JIPTL).¹⁴ These processes represent a collaborative effort across a number of functional areas, supported by computer resources and common databases. Products from this division are used to communicate tasking and guidance for the planning and conduct of airpower operations.

The Combat Operations Division monitors and executes command and control of airpower. *Annex 3-30* identifies four teams: offensive operations, defensive operations, senior intelligence duty officer (SIDO) team, and the interface control team. These teams manage time-sensitive target (TST) operations, theater missile defense (TMD), and joint suppression of enemy air defenses (JSEAD). Through the SIDO, they manage intelligence requirements supporting operations. They also propagate any situation-based changes to the ATO and ACO, as well as generating the Airspace Control Plan (ACP) and the Air Defense Plan (ADP). The interface control team manages and maintains the communication infrastructure connecting the C2 enterprise.¹⁵ This division has a mix of collaborative planning processes and real-time execution

processes. Additionally, execution of these tasks is heavily reliant on communications with either forward C2 nodes or with platforms executing missions. Further, all of this information needs to be reconciled into a common picture of the battlespace so that operational opportunities can be recognized and exploited.

The next division is Intelligence, Surveillance and Reconnaissance. *Annex 3-30* identifies four core teams here: the analysis, correlation and fusion team; the targets/tactical assessment team, ISR operations team; and the processing, exploitation, and dissemination (PED) management team. This division has operational and informational roles. It provides planning and execution for airborne ISR, as well as providing information in the form of ISR support to inform other AOC processes, such as planning, execution and assessment.¹⁶ This division has requirements for collaboration, access to communications and network support, and access to role-specific information technology similar to those of the Combat Plans Division and the Combat Operations Division, with a focus on ISR missions and products.

The Air Mobility Division is the final core division in the AOC. The Air Mobility Division. *Annex 3-30* identifies four teams: the airlift control team, the air refueling control team, the air mobility control team, and the aeromedical evacuation control team. The division's primary function is coordination at the AOC commander's timing and tempo: with the director, air mobility (DIRMOBFOR); with the 618 AOC, and with the theater deployment distribution operation center.¹⁷ Because its role is primarily one of coordination and support to collaborative planning, its processes would be reliant on databases, communications, and collaboration.

When considering schemes to improve AOC resiliency, it is important to ensure that the functions and products discussed above and summarized in table 1 below can still be performed.

Table 1. AOC Elements and Products

AOC Element	Products
Strategy Division	Air Operations Plan Air Operations Directive Other COMAFFOR guidance
Combat Plans Division	Area Air Defense Plans Air Tasking Order Airspace Control Order Special Instructions Joint Integrated Priority Target List
Combat Operations Division	ATO/ACO Changes Airspace Control Plan Air Defense Plan
ISR Division	Reconnaissance, Surveillance, and Target Acquisition Annex to ATO Update to IPOE Air Component Target Nomination List Intelligence Summaries
Air Mobility Division	Airlift Apportionment Plan Air Refueling inputs to MAAP, ATO, ACO, SPINS DIRMOBFOR Coordination Theater Deployment Distribution Ops Center Coordination Coordination with 618 AOC

Command and control depends on more than just the AOC. The AOC is the senior element of the Theater Air Control System (TACS).¹⁸ The next level down includes subordinate C2 nodes, such as airborne warning and control system (AWACS) aircraft, control and reporting centers (CRC), and air support operation centers (ASOC).¹⁹ Additional C2 is provided by the tactical air control party (TACP), which supplies air support to army units as a subordinate of the ASOC. The TACS also includes the JSTARS aircraft and forward air controller (airborne) (FAC[A]).²⁰ The TACS provides a distributed command and control network that extends to the entire operational area, and facilitates integration of air defense, air support, and situational

awareness across the air, land, and maritime domains. It also allows for delegation of authority to lower levels in the C2 hierarchy, accelerating response to critical changes in the battlespace.²¹

As the TACS is already a distributed system, it has some resilience designed in.

Multi-Domain Command and Control Concepts

The next set of concepts relates to Multi-Domain Command and Control (MDC2).

MDC2 is called out in the *Air Force Future Operating Concept* as the next step in the evolution of the core mission that began as *Coordination of Air Defense*, and became *Command and Control*.²² MDC2 tasks are accomplished by the Multi-Domain Operation Center (MDOC).²³ The MDC2 vision, as described in the draft *Multi-Domain Command and Control Operating Concept*, (CONOP) is:

Achieve **integrated awareness** of the operational environment to enable rapid discernment of decision-quality information, integrate **global and regional** capabilities with effective command relationships and operate with **agility and resilience** in, from, and through the air, space, and cyberspace domains.

[emphasis in the original].²⁴

The bold terms are defined in detail in the draft CONOP. To summarize, integrated awareness enables decisive choice through a holistic discernment across all dimensions (domain, geography, etc.) of the battlespace.²⁵ Global/regional integration is the dynamic and seamless application of any forces that may best, or opportunistically, bear across all boundaries and domains.²⁶ Operational agility and resilience are the ability to operate quickly across all domains to preclude an enemy response, while maintaining effectiveness against enemy action and disruption.²⁷ This vision is realized in the five capabilities proposed for MDC2.

The MDC2 CONOP identifies five functions required for executing the MDC2 vision. These are battlespace awareness, strategy and design, planning and tasking, execution, and assessment. Battlespace awareness aims to provide a holistic understanding of the operational environment spanning all dimensions of the battlespace.²⁸ Dimensions would include domain, geographic region, functions, etc. Strategy and design uses operational design approaches to determine to what degree each domain must be controlled to accomplish campaign objectives.²⁹ Planning and tasking use operational art to translate the operational concept into detailed plans for execution.³⁰ Execution focuses on accomplishing the tasked plans, monitoring changes in the operational environment and dynamically adjusting tasks as the environment changes in response to operations.³¹ Finally, assessment links the outcomes of operations to progress toward JFACC and JFC objectives.³² Table 2 provides a summary of how these functions map into the existing AOC and evolve into the proposed MDOC concepts.

Table 2. Multi-Domain Command and Control Function Crosswalk

AOC Division (MDOC Team)	MDC2 Function	MDC2 Product
ISR Division	Battlespace Awareness	Multi-Domain Operational Picture, Intel inputs to other processes
Strategy Division (Strategic Design)	Strategy and Design	AOD Equivalent Air/Space/Cyber Campaign Concept
Strategy Division/ Combat Plans Division (Tasking)	Planning and Tasking	Integrated Tasking Order (ITO) Global/Regional Integration
Combat Operations (Operations Execution)	Execution	Command and Control, Operational Agility Dynamic ITO update
Strategy Division (Rapid Assessment)	Assessment	Inputs to JFC assessments

Synthetic Environment Technologies

This section of the paper provides an explanation of different types of virtual reality technologies, introduces current commercial systems, and explores the applicability of those technologies and systems to command and control functions and processes.

Terminology

There are three top-level schemes for immersing operators in synthetic environments: virtual reality, mixed reality, and augmented reality. Up to this point, this paper has used virtual reality as an overarching term for all of these schemes, in keeping with popular usage. True *virtual reality* (VR) is defined more specifically as presenting an operator with the perception of being in a place other than where he actually is.³³ A full-motion flight simulator would be an example of VR. In *mixed reality* (MR), the operator perceives their actual location, but synthetic objects are placed in their perception, and behave as though they are a part of the environment.³⁴ For example, a virtual showroom might feature a headset that allows the operator to see and interact with a virtual car. The car would appear to be in the showroom. The operator could walk around the car and see it as though it were actually there. Conversely, a real object could be placed in an artificial environment. As an example, this occurs when a camera is used to bring real-time video of the operator's hands and keyboard into a VR workspace so that the operator can see what he is typing as he types. In *augmented reality* (AR), digital information is added to one's perception of the real world.³⁵ The image presented in the combining glass of a heads up display (HUD) or helmet-mounted display (HMD), augmenting a view of the real world with digital text and symbols, is a good example of AR. VR, MR, and AR provide the technology basis for what is popularly referred to as virtual reality.

VR can be further decomposed along sensory lines. Purely visual VR can be achieved with a domed environment, in which the visual environment is displayed on the interior surface of the dome, as in a planetarium,³⁶ or through stereoscopic projection viewed through lenses that present the stereoscopic image to each eye separately, as in a 3-D movie theater. It can also be achieved by directly rendering stereoscopic digital images and projecting them into the eyes with a head-mounted display. In the case of the planetarium, the perspective is the same no matter how you move about inside the planetarium. In the case of the 3-D movie, the perspective is based on the positioning of the original camera that shot the scene. In the case of the head-mounted display, the perspective can change dynamically if the operator's motion and head position can be tracked, and if the computer rendering the scene is fast enough. Auditory VR can be achieved through directional audio, which gives the illusion of sound arrival angle and range-based intensity.³⁷ Such sounds could be natural, or they could be specially created to cue an operator to a specific item of interest. For example, a warning klaxon noise could be played from the direction of the physical location of an internet protocol router that is under cyber-attack. The attack doesn't actually make any real noise, but the representation of the router can make a unique sound to alert an operator of the attack and its direction of arrival in the virtual environment. Haptic VR involves the sense of touch. This can be as simple as the stick-shaker in a cockpit simulator that creates the illusion of wind buffet due to an impending stall in a simulated aircraft, or as complex as an array of actuators that stimulate an operator's hand to "feel" the pressure associated with grasping an object.³⁸ Combinations of these different sensory stimuli can be used to create various levels of immersion. *Immersion* is the degree to which the virtual environment appears "real" to the operator.³⁹ *Presence* occurs when the degree of immersion is sufficient to give the illusion that the perceived, rather than actual, environment is

real.³⁷ For the purposes of this paper, an environment is real if the individuals perceiving it can accept it sufficiently to accomplish their assigned tasks without having to leave that environment.

Technology

The technologies for achieving virtual reality are actually quite old. Charles Wheatstone is credited with the invention of the stereoscope, which allowed the combination of two, slightly offset images, to give the illusion of depth in the early 1830's.³⁸ Stereo sound technology was first demonstrated in 1933.³⁹ Force-feedback systems date back at least as far as hydraulic flight control systems, where they created the illusion of aerodynamic forces being fed back to the pilot from control surfaces. Computer technology has improved the quality of the experiences that can be generated through these technologies and fused them to create the illusion of presence in a virtual space.

Buxton and Fitzmaurice provide a good discussion of the types of VR technologies that are currently in use. Although this taxonomy summary was written in 1998, the three classes described are still in use today. First, there are helmet-mounted display systems. These systems present the user with a stereo view of an artificial environment in place of their view of the actual environment. Next, there are the computer augmented virtual environment (CAVE) systems. CAVEs use one or more 3D panels, coupled with motion tracking and synchronized, shuttered glasses to achieve a stereo 3D effect. Finally, there are chameleon systems. These systems track the position and orientation of a handheld display to render views of a virtual reality.⁴⁰ Each class of systems has advantages and disadvantages that allow them to be matched with command and control tasks.

HMD systems are best-suited for individuals operating on individual tasks or tasks where the interaction of another does not have to have realistic presence. Any interactions in an HMD

system will be with virtual representations of real-world entities and items, which will only be as real as the data driving the representation allows.⁴¹ For example, another person might be represented by an avatar. That avatar may simply be an image of the person. It may include the location and orientation of the person in the virtual environment. It may be a simplified 3D model of the person, possibly with some degree of articulation, reflecting data from some controller or motion-tracking system. The same limitation applies to the user himself. Unless the user is visually represented in the environment, he is essentially a disembodied viewpoint. Use of tracked, hand-held controllers or data gloves provides the ability to interact with the environment and enhances the sense of presence. Cameras can also assist by bringing critical elements of the real-world into the artificial environment. For example, a camera that captures the real-world keyboard and the operator's hands helps with typing tasks. For C2 tasks, the HMD offers the ability to share a common environment when the environment is more important than the people in it. Multiple individuals can examine the same environment from different perspectives and collaboratively work within it.

CAVE systems are best-suited for environments that require long-term immersion or local interaction with other people. CAVE overcomes the major drawback to HMD systems: HMD systems can be fatiguing when one has to wear cumbersome headgear for an extended time. CAVE also allows individuals at the same site to experience a shared virtual environment. Shared is the key word, however. The CAVE is keyed to a single user's perspective, which means that other users, at the local site, have limited ability to fully interact with the environment.⁴² CAVE also has the same drawback as HMD when it comes to remote participants; they must be represented as avatars. For C2 tasks, a CAVE would be preferred for

lengthy tasks performed by local teams in collaboration with other teams or individuals at remote sites.

Chameleon systems are suited for lightweight, portable applications, especially those where immersion is not particularly useful. These systems give one a window into a virtual world that is independent of other users in the physical space. Where individuals at a local site were restricted to a single viewpoint in the local CAVE, each user would be able to have a unique viewpoint of the shared environment, limited by the size and resolution of the display. It still requires avatars for any local or remote user that should be represented in the artificial environment, as with the HMD system.⁴² For C2 tasks, this type of display might be suitable for viewing the common operating picture or multi-domain operating picture for a particular site or in an austere environment using a tablet or smartphone platform. Coupled with appropriate communications equipment and network connectivity, it could enable remote tactical C2 support.

Methodology

This paper uses a problem-solution approach to address the thesis. It begins with a summary of the emerging threat environment, demonstrating that defense of monolithic command centers becomes less feasible over time, given current threat trends. It then examines the concept of multi-domain command and control and the emerging concept of operations for the Multi-Domain Operations Center (MDOC), highlighting areas of that concept that improve upon the resiliency of the Air Operations Center (AOC). The problem emerges from the timing of implementation of the MDOC as an operational element of MDC2. The timing does not support improved resilience in 2025. In the solution section, it will be shown that many MDOC capabilities, especially those associated with resilience can be operationalized much earlier through the adoption of collaborative, virtual presence through shared virtual reality.

Problem: Enabling Resilient Command and Control

2025 Threats to Command and Control

Threat Environment

Regional C2 nodes, especially forward nodes, face a grave and increasingly more lethal threat environment. In addition to theater and intermediate range ballistic missiles, maneuvering and advanced semi-ballistic threats, space, cyber, and electronic warfare threats, new capabilities based on directed energy, high-power microwave, and small drones create a survivability challenge for forward positions. In some cases, forward may include any position in the geographic commander's area of responsibility. Current C2 is based on the TACS as previously discussed. If TACS elements are not resilient in this contested environment, then it follows that C2 will degrade to the extent that those elements are not available. The following discussion outlines the impact of the expected threats on C2 across the geographic regions.

Theater and Intermediate Range Ballistic Missiles

The ballistic missile threat is expected to significantly impact the survivability of forward bases in the 2025 timeframe, with the ability to reach most key facilities in the geographic combatant commanders' areas of operations. These threats are particularly intense in the Pacific and European AORs, and are developing in the CENTCOM AOR. Table 3 and figure 4 illustrate this point. While fixed defenses may be able to stop some incoming attacks, the levels of attack possible in 2025 are likely to overwhelm existing defenses. One senior researcher at RAND puts the number of TBMs required to saturate a base's defenses, destroy parked aircraft, and prevent airfield operations at 30-50.⁴⁷ In the Pacific theater, China is projected to have hundreds of weapons that could be used to reduce fixed command and control targets in Korea, Japan, and Guam. Hawaii is still a sanctuary, at least with respect to ballistic weapons, unless current

ICBMs are retrofitted for conventional payloads.⁴⁸ In Europe, Russia has reintroduced intermediate range ballistic missiles with the deployment of the Iskander missile.⁴⁹ Iran has the capability to disrupt the CAOC at Al Udeid with Shahab, Ghadr, and Sajjil missiles, although the accuracy of these systems mitigate against their credibility as a threat.⁵⁰ Weapons systems and capabilities are shown in table 3 below. Fixed, monolithic facilities will be increasingly vulnerable to the ballistic threat.

Table 3. Theater and Intermediate Range Ballistic Missile Threats

Country	System	Range
China ^a	CSS-5	1750 km
	CSS-2	3000 km
	CSS-3	5400 km
	CSS-10 Mod-2	11,200 km
Iran ^b	Shahab	300-900 km
	Ghadar	1600 km
	Sajjil	2000 km
Russia ^c	Iskander-E ^d	280 km

Notes:

a. Office of the Secretary of Defense, *Annual Report to Congress: Military and Security Developments Involving the People's Republic of China 2016*, April 26, 2016. 23-24.

b. Michael Elleman, "Iran's Ballistic Missile Program," August 2015. <http://iranprimer.usip.org/resource/irans-ballistic-missile-program> in the format of the internet. Retrieved April 14, 2017.

c. Missile Defense Advocacy Alliance. "Iskander-M (SS-26)." <http://missiledefenseadvocacy.org/missile-threat-and-proliferation/missile-proliferation/russia/iskander-m-ss-26/> in the format of the internet. Retrieved April 14, 2017.

d. The Iskander-E is a conventional ballistic variant of the Iskander missile, intended for export.

Maneuvering Conventional and Advanced Threats

Existing C2 are more significantly imperiled by maneuvering threat systems, such as air launched and ground launched cruise missiles. These systems provide precision capabilities, based on precision navigation and timing or terminal sensors, especially suited for engaging large fixed targets. They also provide employment options that complicate air defense operations, increasing the likelihood of a successful attack.⁵¹ At the extreme, hypersonic cruise

missiles with active terminal guidance offer rapid, maneuverable, survivable attack options.⁵² As these systems are deployed in greater numbers and proliferated worldwide, industrial-scale, fixed operations centers become less and less viable. Table 4 below shows some of the current and projected systems and capabilities.

Table 4. Maneuvering and Hypersonic Weapon Systems

Country	System	Range
China	DF-21/HGV ^a	2000-3000 km
	DF-31/HGV ^a	8000-12,000 km
	DH-10 ^b	2000 km
	H-6/LACM ^b	3300 km
Russia	Iskander-M ^c	400-500 km
	SSC-8 ^d	500-5500 km

Notes:

a. Bradley Perret, Bill Sweetman and Michael Fabey, “U. S. Navy Sees Chinese HGV As Part Of Wider Threat: China demonstrates a hypersonic glider,” January 27, 2014. <http://aviationweek.com/awin/us-navy-sees-chinese-hgv-part-wider-threat> in the format of the internet. Retrieved April 14, 2017.

b. Office of the Secretary of Defense, *Annual Report to Congress: Military and Security Developments Involving the People’s Republic of China 2016*, April 26, 2016. 23-24.

c. Missile Defense Advocacy Alliance, “Iskander-M (SS-26),” <http://missiledefenseadvocacy.org/missile-threat-and-proliferation/missile-proliferation/russia/iskander-m-ss-26/> in the format of the internet. Retrieved April 14, 2017.

d. David Alexander and Steve Holland, “U.S. believes Russia deployed new missile in treaty violation,” February 14, 2017 <http://www.reuters.com/article/us-usa-russia-missiles-idUSKBN15T2CS> in the format of the internet. Retrieved April 14, 2017.

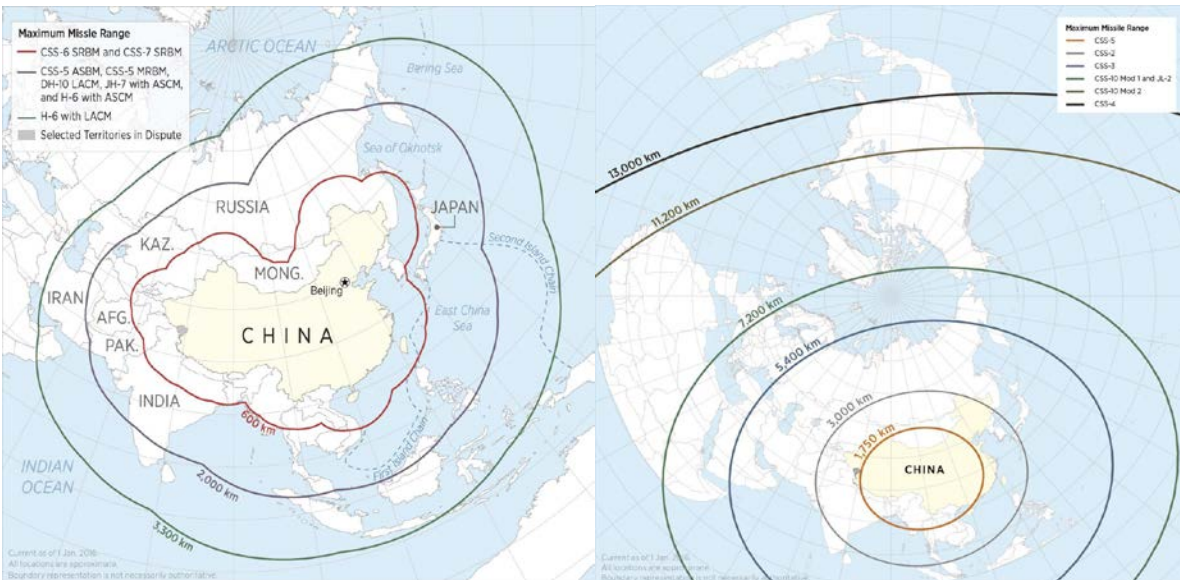


Figure 4. Chinese Missile Threat to Forward Bases

(Reprinted from Office of the Secretary of Defense, *Annual Report to Congress: Military and Security Developments Involving the People's Republic of China* 2016, April 26, 2016. 23-24.)

Cyberspace and Electronic Warfare

Not only do large, fixed C2 nodes present an imminently targetable spatial presence, they also present a targetable nexus in cyberspace. For example, the \$60 million CAOC facility at Al Udeid, contains 67 miles of fiber, thousands of computers, and dozens of servers.⁵³ Physical components such as switches, fiber, and cable lines neck down as they flow toward the AOC, creating critical targets that can cut the AOC out of the loop. Additionally, these critical linkages represent points where cyber data extraction or insertion could be used to develop intelligence about operations or corrupt the planning, controlling, and assessing functions in the air operations cycle. The interdependent nature of air, space and cyberspace that gives the USAF operational agility, also exposes the USAF to cross-domain vulnerabilities that enemies will try to discover and exploit.⁵⁴ Finally, over-the-air channels, provided by line-of-sight links between air, space, and ground stations can be interdicted as they flow into the AOC through the use of electronic warfare assets. These are expected to include advanced radio-frequency (RF) and non-

nuclear electro-magnetic pulse weapons.⁵⁵ In any case, the adversary's targeting problem is simplified by the centralized nature of the AOC construct.

Space

Fixed AOC locations also act to simplify the space targeting problem. Given the fixed (or at least highly predictable) nature of orbiting bodies, their limited capacity for maneuver due to the expense of boosting additional fuel mass to orbital speeds, and the convenience of geosynchronous orbits, it is relatively easy to determine which satellites might support an AOC in a particular location. Further, the military is reliant on large, expensive satellites that are not replaced in an inexpensive or timely manner. Ground-based, ground-launched, and space-based counter-satellite weapons have a demonstrated ability to disrupt satellites with kinetic effects, directed energy, and electronic warfare, and both Russia and China have demonstrated capabilities and ongoing programs in these areas.⁵⁶ Any theater counter-space campaign could focus its efforts on platforms that service that theater's AOC.

Emerging Threats

Three key emerging threats create further single point of failure issues for the monolithic AOC structure: small drones, directed energy, and high power microwave weapons. Swarms of small, commercially-developed or derived drones could be employed to destroy AOC ancillary structures, such as communication antennas or power delivery infrastructure. They could also be employed against defensive systems prior to a kinetic strike.⁵⁷ If used in an ISR role, they could improve the accuracy of kinetic strikes with pre-strike reconnaissance or in-strike terminal guidance.⁵⁸ Directed energy weapons could be used to counter defensive weapons, making the kinetic threats to theater assets more lethal. High-power microwave systems might be employed to disrupt the thousands of computers concentrated in an AOC. The technologies for any of

these scenarios already exist in the United States, in the form of the directed infrared countermeasure (DIRCM) and counter-electronics high power microwave advanced missile project (CHAMP) systems, and a peer competitor could reasonably be expected to develop them in the near future.

The Multi-Domain Operation Center: Concept and Problems

The MDOC is the desired end state for the MDC2 capability development effort. The AFFOC, set in 2035, identifies the MDOC as the senior element of a new command and control structure, capable of delivering effects in, from and through air, space, and cyberspace. Conceptually, the MDOC mitigates the various threats by providing a relocatable, dynamic, flexible C2 structure that can accept loss of individual C2 nodes and degrade gracefully.⁵⁹ The draft CONOPS identifies three limitations of the current AOC construct. To address this, the MDC2 draft CONOPS employs an operational design approach to arrive at five lines of effort (LOE) to transition from the AOC to MDOC construct. These lines culminate in 10+ years with a nascent MDC2 capability and the goal of achieving a “true global resilient architecture.”⁶⁰

Summary of Problem

This proposed approach leaves the status quo AOC construct in place for at least the next ten years. If the desire is to enable resilience for forward command and control by 2025, it will be necessary to consider a bridging strategy to create options for resiliency as the MDC2 vision is being pursued.

Solution: Accelerating Transition to MDOC through VR Technologies

Current Limitations

As previously mentioned, there are three limits identified in the MDC2 operational concept. First, current situational awareness capabilities are not designed to provide an

understanding of multiple domains simultaneously. Second, current planning tools do not support effective collaboration over multiple warfighting domains. Finally, current command and control concepts do not support agility in that they cannot synchronize effects in, from, or through air, space, and cyberspace.⁶¹ The MDOC, as described in the AFFOC, is an attempt to incorporate these features in a future command and control center construct. During the time the MDOC is under development, virtual reality technologies can be used to mitigate these limitations and move the capabilities of the AOC closer to those desired in the MDOC.

Building Multi-Domain Understanding

The first limitation, being unable to provide multi-domain understanding can be thought of as an issue of visualization. To understand the activities across air, space, and cyberspace, one must be able to access and relate relevant information about those domains in a meaningful visualization. There are several ways to classify visualizations. Some are more appropriate for scientific visualization of abstract relationships. Others are more suitable for more concrete relationships, such as spatial, physical, or connection relationships.⁶² Meaningful visualization would be determined by the role of the person observing the information. There are several examples of technologies that display multi-domain data and relate the data within a context. Geographic Information Systems (GIS) display the obvious physical geography, and overlay that with information about crime, data flows, infrastructure, weather, and any number of other things.⁶³ The context for a GIS is obviously spatial; all of the data is organized within that context. Other features of the data are represented by characteristics of the data point itself. Characteristics include the color, shape, size, flash/steady, intensity, associated sounds, and highlighting of the data point.⁶⁴ Google EarthVR⁶⁵ is an example of a VR GIS. A network context may also be useful. In a network visualization, physical and virtual objects are

connected based on their interactions, not necessarily their physical proximity.⁶⁶ Distance in such a space may be determined by the strength of the interaction. This approach might be useful for determining where one might direct a cyberspace activity to maximize an effect in the space or air domains. Or, it might be useful for prioritizing space-domain threats based on their projected point of closest approach. In virtual reality, the inclusion of a third spatial dimension allows directional sound cues, range-based sound cues, kiosk effects (presented information changes with rotation of the data object's representative icon), aspect information, and the ability to consider other viewpoints. Appreciating these relations in a virtual space allows more information to be presented to the planner or operator. Using a common, fused database allows for viewing a common, multi-domain operating picture in multiple, user-defined contexts. Using a shared VR environment allows multiple observers to appreciate the same battlespace context from different perspectives.

What would an appropriate context look like? That would depend on the operator's role in the C2 architecture. Design teams in the Strategy Division would need to see the strategic features of the air, space, and cyberspace domains, as well as the relationships between them. The picture would have to provide a context for identifying strategic nodes and dependencies in air, space, and cyberspace so that campaign planners can determine the decisive points in those domains and design lines of operations (LOO) that engage those decisive points through the most appropriate domain. Similarly, center of gravity (COG) analysis should be multi-domain informed. The Combat Plans Division could use the same sort of visualization, but at higher fidelity, as they consider how to implement the operational concept coming out of the SRD. The Combat Operations Division would need to transition from a two-dimensional air picture to an environment displaying air, space and cyberspace activities affecting the ongoing operations.

This would include friendly and enemy air, space, and cyberspace operations, presented in a meaningful context. The picture would have to be as near real time as possible, to allow flexible tasking of assigned assets, and dynamic control of all assets available across the geographic and global combatant commands. The Intelligence, Surveillance, and Reconnaissance Division would need to be simultaneously aware of friendly and hostile operations in cyberspace, space, air, and the other domains. Within the Division, there may be multiple, simultaneous contexts in place, with analysts cueing each other as events develop from their particular focus area to influence another analyst's focus area. For example, increased network usage at a particular node may correspond to changes in a satellite's orbit, which may also correlate with activity at a known anti-satellite facility. This might not get flagged in a context based on physical locations, but could show up in a network activity-based context. Each context would include data from all three domains, but the significance of the relationship may be more apparent in one context than in another.

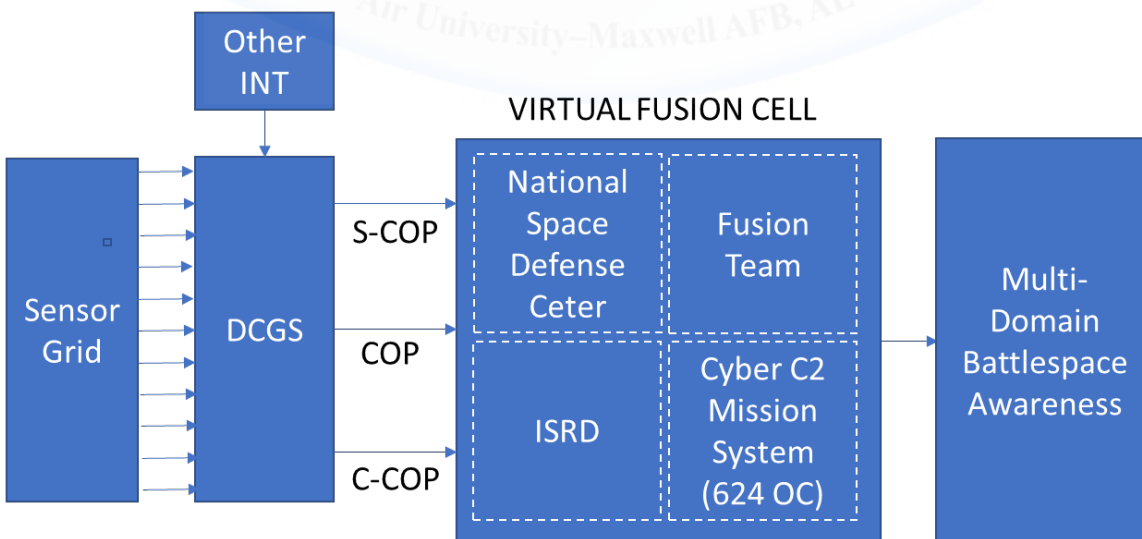


Figure 5. Virtual Fusion Cell Concept

One possibility for enabling multi-domain battlespace awareness would be to establish a virtual fusion cell. This would consist of a distributed collaboration between the geographic

AOC, and the global operations centers for space and cyber. Each entity would supply its operating picture to the fusion cell. Virtual participants would be able to examine all three pictures and collaborate in the development of battlespace awareness. This is illustrated in figure 5. A CAVE at each location would act as the physical point of connection to the virtual space. Designated members from the various AOC divisions could see the multi-domain picture and collaboratively cue each other to cross-domain threats and opportunities. While this would not be a truly fused multi-domain operating picture, it would provide a bridge to that future capability. Mobile and portable CAVEs are commercially available, so this capability could also be used to enhance the resilience of the existing AOC through dispersal of AOC operations.

Enabling Multi-Domain Collaborative Planning

The second limitation that needs to be addressed is the insufficiency of current planning tools for collaboration in multi-domain planning. The long-range solution in the MDC2 operating concept is to have multi-disciplinary teams supported by a multi-domain picture and decision-support automation. In the AOC, this is accomplished by the teams within the divisions, task-specific applications on the global command and control system (GCCS), a common operating picture, and reachback support through various liaison functions. Given the previous discussion of a bridge to multi-domain battlespace awareness, it may be possible to fashion something that moves in the direction of collaborative multi-domain planning using some of the virtual collaboration environments currently available.



Figure 6. View From Inside a Virtual Collaborative Environment

There are a number of collaborative virtual environments available. Figure 6 shows the view from inside a typical commercial product. In this particular environment, *Bigscreen*, each individual's personal screen reflects what is on the monitor in their physical location. Within the space they can view each other's screen, push a screen to the common space as a large display, talk, and share audio and video feeds. The advantage to this particular application is that it allows the users to run whatever they normally would on their computers. In a joint planning scenario, each person might be running a different GCCS application in support of their particular role on the team. Everyone else in the space could observe, comment, and critique the product, or could access it just as they would in the AOC via their physical computer. With head and hand tracking, some social cues, like pointing and focus, add to the sense of presence. Other environments are more or less immersive and interactive. *BasementVR*⁶⁷, is a shared environment that allows interactive creation of 2- and 3-dimensional art, which might be useful

as a 3-D collaborative whiteboard. *AltSpace*⁶⁸ is a collaborative world where avatars interact in user-created spaces. When the access to a large workspace is more important than interactive presence, *Envelop*⁶⁹ allows a user to expand his desktop into a 360 degree virtual space. It also allows the user to bring the real world into the virtual space so that he can see, for instance, his keyboard or physical desktop. Chat and voice chat applications can supply any needed communication interactions. Figure 7 shows a snapshot from that environment. As VR systems continue to proliferate, newer and better applications should be expected.

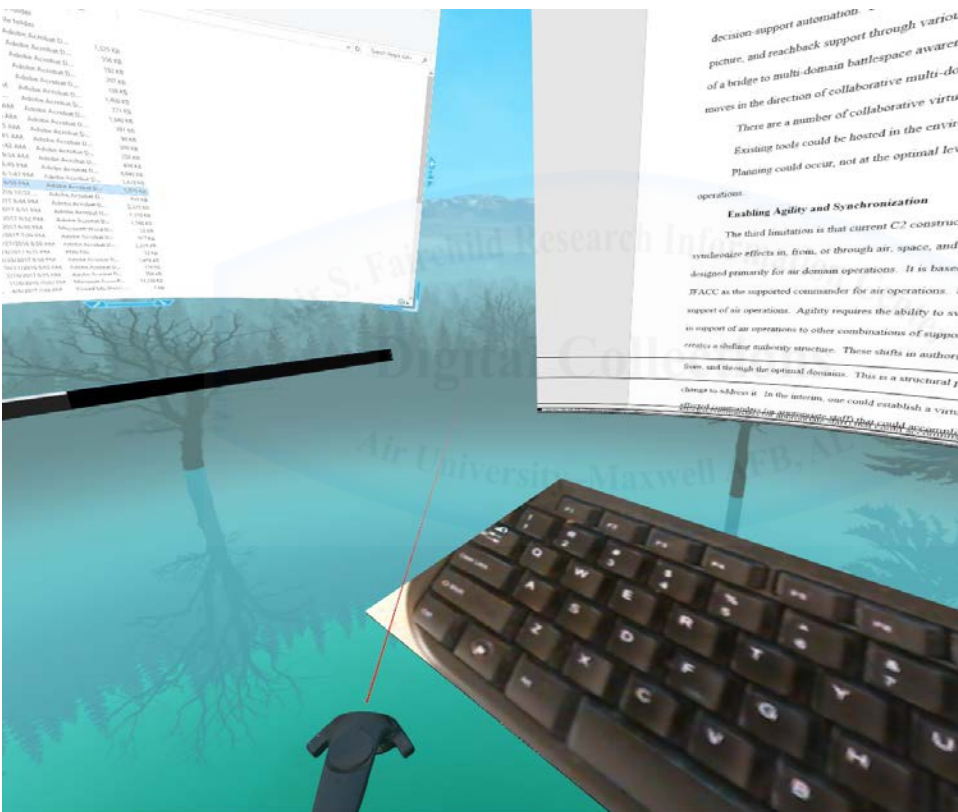


Figure 7. Envelop for Windows Virtual Environment

Planning could occur, not at the optimal level, but well enough to enable multi-domain operations. Consider figure 5 again. Just as the disjointed systems for maintaining domain awareness can be brought into a common virtual space to produce a multi-domain understanding of the battlespace, one could similarly create a virtual joint planning cell that would bring together all of the necessary domain applications and experts in a collaborative environment.

They could participate be present in the virtual space from anywhere with VR hardware support, whether that support is a CAVE, an HMD, or a chameleon unit. Instead of liaison personnel in the physical AOC, actual, working members of reachback organizations could participate in multi-discipline teams, shortening query-response delays to planning cycles. Referring to figure 2 and its long list of subject matter experts (SME), one could greatly improve the timeliness of SME support without appreciably increasing the theater manpower footprint.

Enabling Agility and Synchronization

The third limitation is that current C2 constructs do not provide enough agility to synchronize effects in, from, or through air, space, and cyber. The current structure, TACS, is designed primarily for air domain operations.⁷⁰ It is based on a hierarchic structure with the JFACC as the supported commander for air operations. Space and cyber provide effects in support of air operations, but their C2 occurs at two other operation centers.⁷¹ Agility requires the ability to switch from cyber and space operations in support of air operations to other combinations of supported and supporting operations, which creates a shifting authority structure. These shifts in authority require close coordination to ensure that emergent opportunities are capitalized on and emerging threats are dealt with in, from, and through the optimal domains. This is a structural problem, and doctrine will need to change to address it.⁷² In the interim, one could establish a virtual executive cell comprising the affected commanders (or appropriate staff) that could accomplish the coordination of command relationships in near real time. Virtual reality technology could be used to enable the virtual executive cell. A two- or three-wall CAVE would allow access to the common operating picture and a shared workspace for the staff team controlling the exchange of authority. Exercising in a virtual space would provide opportunities to work out different approaches to transitioning authorities and practice

operational agility. Like the other transitional schemes, this approach is sub-optimal, but enables greater resiliency sooner.

Additional Resiliency Considerations

The schemes discussed above help increase resiliency by moving the enterprise in the direction laid out in the MDC2 operational concept, but they don't directly address the near-term resilience of the AOC and forward-based elements of the TACS. In fact, those issues are identified as a 10+ year goal.⁷³ There are differing views as to how much physical presence is required in the geographic region, but one estimate suggests that 90% of the current presence could be garrisoned in CONUS.⁷⁴ The same technologies that allow virtual collaboration between geographic and global operation centers could be used to virtualize components of the existing C2 architecture, allowing the theater manpower footprint to be reduced. This is accomplished to some degree with LNOs and reachback, but the practice could be extended through VR technology applications. As previously discussed, CONUS SMEs could be integrated into the virtual workspaces instead being in the physical workspaces. Further, AOC personnel could be dispersed to other locations in the theater or CONUS, and still maintain awareness of the regional environment. For forward-based elements of the TACS, HMD VR systems have advanced to the point that they can run from a high-end laptop computer.⁷⁵ This would allow operations to be dispersed or reconstituted anywhere suitable communications are available. In some situations, a chameleon system based on tablet or smartphone technology may be more suitable. The net effect would be to multiply and disperse the targets in theater, reduce signatures in the cyber domain, and shift the bulk of the resources into the relative sanctuary of CONUS with commensurate improvements to resiliency and capacity. The proposed solutions are summarized in table 5.

Table 5. Summary of Proposed Solutions and VR Applications

Problem	Solution	VR Technology
Situational awareness capabilities not designed to provide an understanding of the battlespace that spans all domains	Virtual fusion cell to collectively and simultaneously interpret the separate COPs for Air, Space, and Cyber	CAVE facilities at each geographic and global C2 facility to create virtual presence of a fusion cell. Human interaction achieves multi-domain awareness.
Planning tools and processes do not support effective collaboration over multiple warfighting domains	Collaborative, joint planning cells that leverage existing tools in a synchronized, balanced planning effort	CAVE facilities, collaboration software, room-scale HMD.
C2 constructs do not provide the necessary agility to synchronize effects in, from, or through air, space, and cyberspace	Virtual executive cell, dynamically adjusting authorities in response to shared multi-domain battlespace awareness.	CAVE facilities
Physical resilience of forward bases	Increased dispersed operations to complicate targeting, minimize single-point vulnerabilities.	Multiple CAVE for redundancy at fixed bases/garrison, HMD systems for forward/austere locations, chameleon systems for remote battlespace awareness.

Challenges to Distributed Virtual Operations

If one attempted to implement the suggested incorporation of VR into the AOC to realize a virtual fusion of air, space and cyberspace C2, there are some challenges to consider. First, there is a cultural aversion to virtual solutions, which isn't completely misplaced. Second, doctrinal issues must be resolved before operational agility can be truly achieved by this or any other solution for MDC2. Finally, there are physical and policy issues inherent in any change to military operations, especially those that involve material solutions. These challenges are discussed next.

Virtual Presence is Actual Absence

Schemes to create virtual military teams invoke some degree of controversy. The phrase, “virtual presence is actual absence,” recurs in the literature on distributed operations. Admiral Mullen used it in a speech to the National Defense University in 2005, saying that “We hear a lot about virtual presence today. I believe that for a naval force, virtual presence is actual absence, and that simply won't suffice in the world in which we live.”⁷⁶ This makes sense, as a physical presence is necessary when projecting power or applying kinetic effects. Hukill and Mortensen tie the need for actual presence to building trust and personal relationships through personal contact and shared experiences.⁷⁷ Britten, in his paper on reachback operations, makes a solid case for the JFACC, his key staff, and LNOs being forward.⁷⁸ But, as previously discussed, he also makes a case for moving about 90% of the personnel footprint back to CONUS. The literature on virtual collaboration is mixed. On one hand, Eovito, in his discussion of text-based chat in military C2 points out that virtual collaboration plugs holes in the C2 support architecture and accelerates the OODA loop.⁷⁹ On the other, Bergin, et al. found that text-based virtual collaboration resulted in less accurate results than face-to-face interaction.⁸⁰ It appears that the degree of interaction affects the accuracy of the outcome. Bergin intended to pursue a low-immersion environment (text-based chat) and a high-immersion environment (VR with avatars), but was not able to implement the high-end environment. As a result, his effort was unable to establish the degree of immersion at which performance starts to degrade.⁸¹ It is possible that there are more opportunities for ambiguous communication in the low-immersion collaborative environment. Sonnenwald, et al., identify challenges to communications in C2 that lead to a lack of trust and task failure.⁸² These challenges are exacerbated by reduced interaction, which might explain Bergin’s results. Knowing this, training should emphasize trust-building and employ the

highest level of immersion practicable. AOC-level staff training, in the virtual environment would create common experiences and provide opportunities to identify assumptions and practices that lead to less accurate results.

Doctrinal Issues

As was brought up in the operational agility discussion, the multi-domain command and control concept hinges on developing a solution for rapid transitions in authorities. It is the difference between an air-centric C2 that is more tightly integrated with space and cyberspace, and a fully multi-domain C2. The problem is similar to the problem Hukill and Mortensen identify in their article on flexible command and control of airpower. They argue that the USAF presentation of airpower is optimized for supporting the CCDR, and that it does not decentralize well for levels below that.⁸² The problem with MDC2, is that the exchange of authorities is between CCDRs, and the opportunities and data driving the need for that exchange is at the operational level. So, any shift in command relationships arising from a perishable opportunity has to be staffed up to an echelon that can adjust supporting and supported relationships between STRATCOM/SPACE, STRATCOM/CYBER, and the regional CCDR. Since the intent of operational agility is to employ forces in, from, and through air, space and cyberspace to achieve effects in any other domain at a speed that exceeds the speed of the opponent's decision-loop, engaging another layer of decision-making, at an operationally useful tempo, it is unlikely that true agility can be achieved. Virtually integrating components of 624 OC, 614 AOC, and the regional AOC, should enable cross-domain effects, but probably won't result in true operational agility. This issue must be resolved before operational agility can be realized.

Shared Challenges

Virtualizing the AOC faces the same suite of problems that are currently experienced by any other effort that involves the AOC: security, infrastructure, and the glacial pace of the acquisition system. Common security issues include accreditation of systems and spaces to the appropriate level, secure channels for transferring information, procedures for sharing information with coalition and allied partners, and integrating data exchanges up and down security structures. While a distributed, virtual AOC construct would have more sites, each would have fewer systems and personnel that require security services. Additionally, personnel moved back to CONUS could fall in on existing security enclaves. Infrastructure problems include power, shelter, environmental control, and communication linkages to support connection to the DOD information network (DODIN). The virtualization concept lightens the individual site load, making more sites available for installations. The infrastructure will need to provide enough bandwidth to support telepresence, but technology for managing that already exists.⁸³ Given that secure, suitable facilities and connectivity are available, acquiring and integrating these systems is the next challenge. The AOC is designated as a weapon system.⁸⁴ That puts it under strict configuration control and complicates the process of making changes to it. That results in delay, whether the change is in the current program or driven by this virtualization concept. There are processes for more agile acquisition, notably those employed by the Air Force Rapid Capabilities Office,⁸⁵ which could be employed. AFRICOM or SOUTHCOM might make a good testbed for a lightweight virtual AOC installation.

Advantages of distributed Virtual Operations

Adopting VR technology produces many advantages, among these are reduced risk to theater C2 nodes, increased C2 capacity, improved training, and accession of the commercial

research and development being driven by the demands of the gaming and entertainment industry.

Reduced Risk

Theater risk is reduced by dispersal, signature reduction, personnel hazard exposure, and improved mobility. These work together to complicate an opponent's kill chain. Dispersal from a single, monolithic facility increases the number of targets that the opponent must locate and destroy. It simultaneously makes the value of any particular target less, as the C2 enterprise may be able to continue operating in a degraded state until the destroyed node's capability can be reconstituted. The second risk reduction mechanism is signature reduction, and it is a consequence of dispersal. Distributed operations results in sites that have smaller physical and cyberspace footprints. This makes them harder to detect, and therefore engage. Personnel hazard exposure is reduced primarily by pushing personnel performing tasks that do not require physical presence into the cyber domain and placing their physical bodies in CONUS. It is further reduced by decreasing the likelihood that their physical location in theater will be successfully detected and engaged. Finally, mobility further reduces risk. Mobile installations create an additional resource drain on the opponent in that once detected, a facility must be kept in ISR custody until the opponent engages it. This limits the number of facilities that can be engaged, and reduces available ISR timeline for hunting additional facilities. If the facility relocates while the opponent is engaged in another ISR task, the opponent will not be able to engage it. Forward C2 nodes with the greatest risk would have to move more often, which creates a requirement for rugged, highly-portable gear. Mobility, minimal manning, signature reduction and dispersal make TACS elements difficult to locate and engage in sufficient numbers to deny friendly C2 capability, increasing the TACs overall resilience.

Greater Manpower Availability

The linkage to CONUS facilities enables direct engagement with a greater number of personnel resulting in improved bench depth, rapid recovery from attrition, and opportunities to bring more joint experience to airmen. Improved bench depth when trained personnel supporting a less busy geographic CDR can be flexed to support a geographic CDR that has an emergent need. Also, the lengthy spin-up required to meet theater deployment requirements can be pared down to the minimal training necessary to prepare an airman for his role in the AOC, accelerating manpower availability. Further, LNO personnel can arrange for agency SME personnel to participate directly in AOC processes that require their expertise. This improved access to personnel also influences the AOC's resiliency by enabling rapid recovery from attrition of in-theater assets. Should an in-theater facility be destroyed, its functions could be virtualized until the facility was reconstituted. Finally, with an increased utilization of CONUS-based personnel, more airmen will have opportunities to participate in joint warfighting. This has the positive effect of producing more joint-minded airmen. Greater access to personnel and rapid recovery increase resilience, with the side effect of increasing the jointness of airpower.

Realistic Training

Within the virtualized components of the AOC, there is an opportunity for very realistic training. Simply put, a virtual environment is wholly dependent on the data that informs it. The virtualized AOC will normally run on data supplied from real-world sources. Simulated inputs could turn real-world systems into training systems at the flip of a switch. The only way a participant would know he is in a training or exercise environment would be if someone told him. This provides a way to develop trust in the systems and one's virtual teammates. Training events could be designed to achieve desired training objectives and to emphasize team and trust-

building outcomes. The resulting shared experiences would likely be inferior to face-to-face experiences, but they would still be shared experiences, and they would be representative of the sort of experiences one would have in the actual execution of C2 operations.

Leveraging Commercial Advances

Advances in current VR technology are being driven by the media and gaming industries. This concept for enabling virtual collaboration in the AOC leverages those advances and the resources they represent. Many applications for the high-end VR systems: VIVE, Oculus, and PlayStation 4, are built around game engines. These capabilities are currently being leveraged to support virtual training environment. For example, Booz Allen has used the Unity game engine to develop a virtual operations floor for training cyber defense analysts, as well as egress training for MC-130 crew.⁸⁶ The cyber operations floor, for example, may be useful as an environment for creating an AOC operations floor. As the gaming industry brings more applications into virtual space, the USAF should be mindful of opportunities to leverage other capabilities from industry. The massively multiplayer online (MMO) game sector is especially interesting. In an MMO, thousands of people, from locations all over the world, simultaneously interact in an artificial environment. Some of these games involve command and control of large force on force actions. EVE online is one such game. Fleet battles with thousands of simultaneous players are managed in real time with a fairly simple, user-configurable interface on commercial internet infrastructure.⁸⁷ Interface settings are user-selected, highlighting information cogent to one's assigned tasks. Figure 8 is a screen capture from EVE, showing the interface. Using this interface and voice chat, fleet commanders direct the actions of globally-distributed fleet, wing and squad level subordinates to achieve their objectives. Harvesting robust capabilities from commercial applications has great potential for accelerating multi-domain command and control.

The Defense Innovation Unit Experimental (DIUx)⁸⁸ should monitor this industry for adoptable technologies.

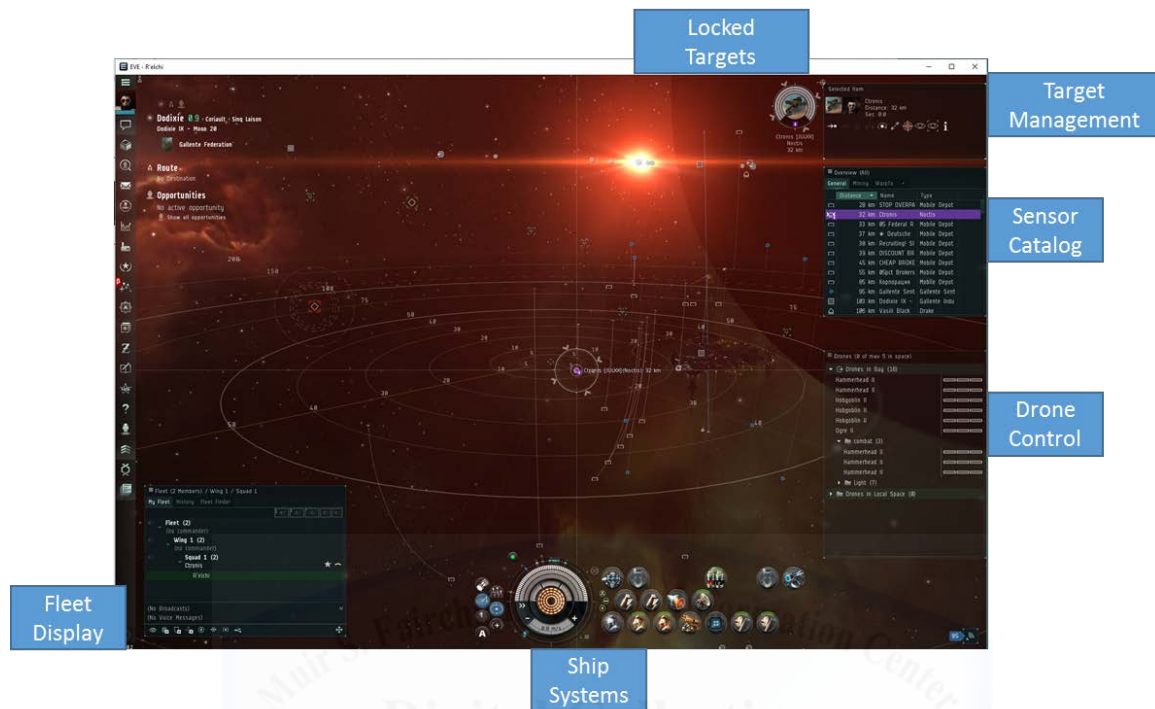


Figure 8. EVE Online Command and Control Interface

Conclusion

This paper's goal was to look for ways to increase the resilience of forward bases and operating locations in the face of a 2025 threat. The 2025 threat is such that any base in Europe, the Pacific, or the Middle East could be considered forward. It specifically examined the ability to provide command and control in that environment. The MDC2 operation concept proposes a resilient solution for multi-domain command and control, but that concept is not projected to be capable for at least ten years. Application of VR technologies were proposed to bridge the gap and introduce some of the desired capability and resiliency. To that end, four initiatives are suggested. First, create a virtual fusion cell comprising personnel from the regional AOC, the 624 OC, and the 614 AOC. This fusion cell will use human collaboration to build battlespace awareness across the air, space, and cyberspace domains until such time as a truly fused multi-

domain operating picture can be fielded. Second, using the same construct, create a virtual planning cell to enable multi-domain strategy, design, and planning and produce integrated tasking orders. Third, create an executive fusion cell, linked to the combat operations division, to dynamically adjust command relationships, creating synchronized multi-domain effects through agile operations. Finally, determine which AOC positions can be accomplished virtually and relocate those personnel to sanctuary in CONUS. For those functions remaining in theater, use VR technologies to distribute operations to multiple locations in theater while maintaining collaboration in the cyberspace domain. The following recommendations address how these capabilities might be realized.

Recommendations

First, the MDC2 operational concept should add a capability transition line of effort that uses available technology to move current AOC capability in the direction laid out in the MDC2 operational concept. This effort would focus on building toward a working multi-domain operating picture through a virtual fusion cell approach, enabling collaborative multi-domain planning, and experimenting with dynamic C2 concepts. Where possible, rapid-acquisition capabilities should be employed. AFRICOM or SOUTHCOM might be a good candidate for piloting these capability development demonstrations.

Second, the ECCT experimentation campaign should include shared, virtual, collaborative spaces. Using VR technologies to support simulation and training should also be considered. Dispersed and distributed operations should be played out to gain an understanding of the tradespace between the efficiency of actual presence and the resilience of virtual presence.

Finally, as commercial VR and gaming technology continue to advance, the USAF should look for opportunities to incorporate best practices from massively multi-player online

games. These architectures are constantly innovating to support the C2 needs of combat operations featuring thousands of simultaneous players communicating via voice, text, and datalinks. The visualization, data-throughput, and user management capabilities may have utility for USAF C2 capabilities. The Defense Innovation Unit Experimental should be engaged and tasked with seeding and harvesting relevant technologies.



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