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Key Points

The drive for relevant command and control lies with a simple goal: empowering highly effective aerospace combat power.

A command and control design must be effective across the spectrum of operational environments.

Creating a successful approach to Advanced Battle Management System (ABMS) and Joint All-Domain Command and Control (JADC2) will require the Air Force to harness advanced technologies like fifth-generation aircraft fusion and machine learning.

High-speed, high-altitude manned command and control, intelligence, surveillance, and reconnaissance (C2ISR) sensor platforms could provide supplementary "look-in" and network-sourced decision-making insights.

An appropriately tiered layer of command must ensure actions taken will result in optimal desired effects to achieve a commander's intent.

Command and Control Imperatives for the 21st Century: The Next Areas of Growth for ABMS and JADC2

By Douglas A. Birkey
Executive Director, The Mitchell Institute for Aerospace Studies

Abstract

The Air Force is at a major juncture in the development of command and control (C2) capabilities. Under the aegis of the Advanced Battle Management System (ABMS) and Joint All-Domain Command and Control (JADC2) programs, the Air Force is pushing ahead with efforts to modernize its C2 architecture by capitalizing on emerging technologies such as artificial intelligence and machine learning. Faced with the heightened threat environment created by America's adversaries, these investments are critical to the Air Force's ability to operate and win in future conflicts. However, this progress demands a holistic risk mitigation approach that blends innovation, operationally mature systems, and backup redundancies.

Over the past two decades, technological advances in the field of networked connectivity, high-fidelity sensors, persistent overwatch by remotely piloted aircraft (RPA), and huge gains in computing power saw seismic advances in combat edge situational awareness and decision-making. The ABMS promises to build on these gains by harnessing machine learning and automation to rapidly process, filter, and direct information from distributed networks of sensors to shooters, creating partnerships designed to deliver optimal effects at the right place and at the right time.

In its drive to modernize, the Air Force cannot risk overlooking the valuable role that air battle managers play within the C2 architecture. While connectivity, automation, and processing power are crucial tools, a requirement still exists for human judgement and engagement, especially in highly complex, dynamic missions where accurate insight is essential for managing risk. Indeed, the Air Force should examine ways of elevating human C2 operators within the ABMS construct. It could do so by extending the life of existing C2ISR aircraft such as JSTARS and AWACS or by replacing these aging platforms with a new class of supersonic aircraft currently under development in the commercial sector. It should also study the potential afforded by alternate aerial operating locations, i.e., onboard aerial tankers, for air battle managers to ensure that they are appropriately staged throughout the operating space. These approaches will mitigate the risks of becoming over reliant on extended communication networks. To maximize the advantages yielded by new technologies, the Air Force must develop a tiered strategy for modernizing its C2 capabilities, one in which the human professional remains at the core.

Introduction

The warfighting potential measure of merit for the Air Force is often intertwined with the size of its aircraft inventory. However, while numbers certainly matter, airplanes alone do not yield airpower. It takes a combination of sound strategy, effective operational concepts, and an accurate execution of commander's intent to turn the potential of these tools into actual mission accomplishment. This is precisely why information advantage, connectivity, and command and control (C2) stand as one of the U.S. Air Force's top modernization priorities. As former Air Force Chief of Staff General (ret.) Dave Goldfein explained, "Victory in future combat will depend less on individual capabilities and more upon integrated strengths of a connected network for coalition leaders to employ."[1] Said another way, success all comes down to understanding the operating environment and employing the right set of assets at the proper time and place to best achieve desired results, while minimizing one's own vulnerabilities. This requires U.S. forces to secure battlespace situational awareness more rapidly and more accurately than what an adversary can achieve, maintain robust and reliable connectivity, and the ability to promptly translate information into appropriate actions. It also necessitates proactive leadership at each level of an operation to ensure the commander's mission intent is achieved within the realities of a dynamic combat environment.

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Today the Air Force is at a major juncture in realizing these capabilities: balancing the push for innovation and technology with the need for command and control. The notion of what distributing information at machine speeds, connectivity, and C2 mean to future operations is rapidly evolving thanks to new technologies and the demands of increasingly lethal threat environments. Air Force leaders are rightfully calling for a broad range of new systems to maximize opportunities afforded by emerging information technologies to give U.S. warfighters decision dominance in the future battlespace. The technical means of this effort is known as the Advanced Battle Management System (ABMS), with Joint All-Domain Command and Control (JADC2) as the broader force management construct. In the rush to modernize its activities in this area, the Air Force risks focusing too much on the technical aspects of its future networks without giving the same consideration to the fundamentals that underpin effective decision making in warfare—commanding and controlling. Air Force leadership's overriding focus on network technology when they discuss this endeavor reflects this imbalance. It is not enough to buy a new tool and expect a specific outcome without considering broader mission parameters.

This policy paper contends that it is time for the Air Force to broaden the conversation past specific technologies and decide where the C2 centers of gravity will reside within this new system, what they will look like, and how warfighters will effectively employ them across the spectrum of conflict. C2 is predominantly a human endeavor that can be assisted by technology but cannot yet be replaced by it. Building better networks and harnessing new capabilities like artificial intelligence (AI), automation, and machine learning alone will not yield effective C2. It takes an ecosystem of operational level commanders, air battle managers to bridge the operational and tactical divide, and air crews empowered with relevant information to net mission results. These are specific functions that must be appropriately tiered throughout the battlespace to ensure they can connect effectively with their mission partners and execute respective mission functions. Current Air Force C2 plans lack a clear concept of operations (CONOP) regarding this construct.

On top of this, in its haste to develop new systems, the Air Force must not trade one set of vulnerabilities for another. Progress demands a holistic risk mitigation approach that blends innovation, operationally mature systems, and backup redundancies. A strategy built primarily around too many aggressive technological efforts that depend on near-term, ambitious, and concurrent innovations is a perilous one. The situation is even more challenging given uncertainties in the future budget climate--resources to bail out a program mired in unanticipated problems will likely be unavailable. Solutions must also speak to the full range of probable mission scenarios, not just one portion of the threat spectrum.

The importance of operationally relevant information, communication systems, and effective C2 is not a new idea. These elements have long stood as a foundational aerospace power imperative. History underscores that this is something the Air Force must get right.

Anyone questioning this should reflect upon the summer of 1940, when Germany, having just occupied France, was set on invading the United Kingdom. An air offensive was the first component of the attack. The Royal Air Force (RAF) was in an exceedingly challenging position, possessing 446 operational fighters against Germany's 3,500 combat aircraft amassed across the English Channel. When the Luftwaffe raids commenced, the RAF's relative strength eroded rapidly. In the 10 days between August 8 and August 18, 1940, the RAF lost 154 pilots, with only 63 green airmen available from training squadrons to backfill casualties.[2] Despite these overwhelming odds, the British forces prevailed. While there were a variety of factors shaping this outcome, three proved essential in ensuring that the RAF's incredibly limited supply of fighters were employed in the most decisive method possible: a robust sensor network in the form of radar and observers; a voice communications network; and a highly integrated C2 enterprise whereby trained personnel gathered federated sensor inputs, fused this data, and communicated actionable information to fighter pilots. To put it bluntly, information, connectivity, and C2 helped save England when the chips were down.

It is encouraging that the Air Force lists programs like ABMS and JADC2 as top priorities, for it reflects an acknowledgement regarding the criticality of information, connectivity, and C2. However, this success demands a holistic approach that extends past networks.

C2 Design Principles to Meet Tomorrow's Challenges

The drive for effective, relevant C2 lies with a simple goal: highly effective aerospace combat power. The United States Air Force (USAF) finds itself in a similar position to the British in the summer of 1940—equipped with too few resources and facing a burgeoning set of threats. As former Secretary of the Air Force Barbara Barrett explained, "The Air Force as currently constituted is too small to do what the nation expects of it."[3] In fact, today the USAF has never fielded such a small and old aircraft force since its founding in 1947. Whether looking at over two-thirds of the bomber force predating the 1962 Cuban Missile Crisis, or a fighter inventory predominantly acquired before the world wide web was invented in 1989, the

USAF lacks the capacity and capabilities increasingly required in modern high-end conflict. Capable airframes with sufficient stealth capacity and the information-age attributes required to challenge peer competitors are in incredibly short supply—just 20 B-2s, 186 F-22s, and approximately 300 F-35s are presently fielded. The rest of the USAF's combat forces consist of several thousand non-stealth, industrial-age airframes with outdated information-centric attributes.[4]

This shortfall in capacity and capability matters a great deal because the global threat environment presents an incredibly broad set of hazards where optimal force employment will prove crucial. China and Russia are pressing the United States at the top end of the threat spectrum; middle-weight regional powers like North Korea and Iran are presenting an outsized threat due to their nuclear programs; and non-state actors like the Islamic State (ISIS) and al Qaeda are continuing to destabilize key regions around the globe.

Lacking an adequate toolkit, leaders may have an insufficient range of policy options to deal with these threats. Acknowledging the unfunded mandate that has been levied on airmen for far too long, in 2018 the Air Force announced the need to grow to 386 operational squadrons. There comes a point where security requirements necessitate sufficient numbers of aircraft and space systems to provide core numerical capacity in the face of numerous, concurrent global threats.

These force structure shortfalls increase the need for the Air Force to create an enterprise of information systems, connectivity, and C2 capabilities that maximize the combat potential of each of its weapon systems. This will require a highly interdependent, complementary approach to maximize mission effects. It is like a three-legged stool, where each leg of the enterprise is required for mission success. Stated in a more holistic fashion:

> *This concept can be envisioned as a "combat cloud"—an operating paradigm where information, data management, connectivity, and command and control (C2) are core mission priorities. The combat cloud treats every platform as a sensor, as well as an effector, and will require a C2 paradigm enabling automatic linking, seamless data transfer capabilities, while being reliable, secure, and jam proof. The combat cloud inverts the paradigm of combined arms warfare—making information the focal point of military operations, not operational domains. This concept represents an evolution where individually networked platforms—in any domain—transform into a "system of systems" enterprise, integrated by domain and mission-agnostic linkages.*[5]

It also involves building multiple pathways of achieving desired effects and presenting the adversary with a highly disaggregated kill-chain enterprise where there are no central points of vulnerability.

Recognizing this imperative, the Air Force actively seeks to harness the latest developments in sensor technology, data processing, machine-aided decision tools, and connectivity in ABMS and JADC2. These efforts stand as the service's top goals. Former Air Force Chief of Staff General David Goldfein who charted this new vector, explained:

> *What I am talking about is a fully networked force where each platform's sensors and operators are*

connected not by point-to-point circuits, but in a mesh network that is highly resilient and self-healing. And they are not just connected either—they are part of a command and control system that automatically pairs the right sensors to the right targets, fusing data from all platforms and sensors and identifying and refining targets automatically and allocating weapons to targets, allowing us to converge effects in a synchronized and simultaneous manner.[6]

What General Goldfein described, and what his successor General Charles "CQ" Brown continues to pursue, is non-negotiable if the Air Force is going to remain a viable, relevant, and competent combat power. Just as technologies like radar and processing power reshaped combat aviation, so too will this highly networked aerial command and control construct. As 25th Secretary of the Air Force Barrett explained, "Modernizing is all about being connected, being able to have instant access to usable information."[7]

However, for this new vector to succeed, the conversation needs to move past its focus on connectivity. Networks are obviously crucial tools, but they are not warfighting ends in and of themselves, nor will they magically manifest C2. For it to meet the future threat environment, the Air Force must consider three overarching principles for its ABMS and JADC2 visions:

1. **A command and control design strategy must integrate technology and human intellect to ensure command intent is translated into desired action.** The rapid flow of raw data or the existence of potentially actionable information does not manifest mission accomplishment; it takes an appropriately tiered decision-making network—from the strategic, to the operational, to the tactical level of operations—to ensure commander's intent is met. Connectivity, automation, and processing power are crucial tools in this regard, but a requirement still exists for human judgement and engagement. This is especially true in highly complex, dynamic missions where accurate insight is essential for managing risk. C2 actors must be tiered effectively throughout the battlespace in alignment with their assigned responsibilities. This will bolster the chances for assured connectivity to relevant data flows and mission partners.

2. **A command and control design must allow the Air Force to carefully manage the operational risks of overly aggressive innovation as it rapidly assimilates high-leverage systems and processes.** The Air Force today is innovating on a scale not seen in decades. Given the post-Cold War procurement holiday, an overwhelming focus on low-end technology threats in the wake of 9/11, and the deleterious impacts of the 2011 budget control act, the recent push to embrace the potential of new technologies and concepts is essential for the Air Force to competently face growing threats now and over the next several decades. However, it is crucial not to confuse technological potential with guaranteed operational reliability in the near- to mid-term. Viable fallback capabilities must exist if results fail to meet schedule or functionality goals. New solutions must also seek to provide alternate courses of action to achieve mission goals in case adversaries are able to defeat the revised approaches. One vulnerability should not be exchanged for another—the goal must

focus on broad improvement. This is a commonsense risk management strategy, where one solution set does not sunset until the other is tested under the most demanding stressors and proves its operational prowess.

3. **A command and control design must be equally effective across the spectrum of operational environments.** While the peak demands of great power conflict must drive investment priorities and associated concepts of operation, the resulting capability design choices must also be flexible to achieve mission results throughout the full range of operational environments. A significant number of military operations still occur at the mid-tier and low-end of the threat spectrum. Solutions must be able to scale across the threat spectrum without a loss of speed and effectiveness in command and control. People do not drive to grocery stores in F1 race cars—a variety of options must exist to match the mission requirements to available tools.

Such design principles have not been at the forefront of current public conversations, and, instead, attention is focused on a purely technology architecture applied to narrow operational scenarios. Form must follow function and failing to pursue this balanced approach could result in a highly suboptimal system.

DOD's Theater Battle Management Core System (TBMCS) experience stands as a cautionary tale in this regard. Designed in the late 1990s and early 2000s to automate planning and control of the air component, the TBMCS program violated all three of these design principles. As one Air Force Institute of Technology assessment declared, "The government did not produce a concept of operations, key operational performance parameters, or a system specification for the contractor."[8] The TBMCS program sought to build one software tool of federated subroutines that would effectively software code the air component into a new automated age. The human interface was a secondary concern. It was difficult to understand, hard to train new users, and exceedingly challenging to use. It was also built around a model of high-end operations that would stick to a rigid air tasking order planning cycle.

This was the exact opposite set of circumstances that unfolded in Afghanistan and Iraq, which involved highly dynamic operating situations where rapid processing of information drove time sensitive targeting.[9] Many TBMCS sub-components proved wholly deficient during these operations. For example, the U.S. tanker planning cell located in Qatar supporting joint operations found the TBMCS fuel planning routine unusable and regressed to arduous manual computations to determine the tanker plan. They then had to manually enter their calculations into the system to get it to appear in daily air tasking orders.[10] This was an egregious example of technology, not pragmatic mission requirements, driving processes.

A MITRE study evaluating the program said it well: "The acquisition community had a utopian vision of a single modern, integrated, joint C2 system, but had no operator requirements to support it and no CONOPS that described how the system would work as single integrated capability."[11]

ABMS and JADC2 must not risk the same fate. A recent GAO report on ABMS sounded this concern, especially over the notion of well-understood program requirements: "The only existing documentation of ABMS's requirements resides in the ABMS Initial Capabilities

Document from 2018, which generally focuses on the capabilities needed to replace AWACS. That document does not address the expanded JADC2 requirements and capabilities ABMS is expected to eventually fulfill."[12] This suggests there is room for growth based on time-tested tenets of information, connectivity, and C2.

Presence at the Combat Edge: An Enduring Requirement for Air Battle Management

Creating a successful ABMS and JADC2 approach will require the Air Force to harness advanced technologies like 5th generation aircraft fusion, machine learning, and seamless system teaming. It will also require the service's tactical C2 experts—its air battle managers—to operate throughout the battlespace, including at its leading edge. Current C2ISR aircraft like AWACS and JSTARS have continually demonstrated the value of the air battle manager in complex, highly dynamic, large-scale missions.

The USAF's next-generation air battle managers should reside on mission-specific aircraft that have an open mission system architecture, highly modular sensors that can be swapped as demands require, high levels of onboard processing, organic sensors, and advanced networked connectivity. Added to this, the aircraft should seek to harness promising developments in the field of supersonic flight. Supersonic aircraft are being designed by multiple firms that would allow for the carriage of mission systems and air battle management crew. These aircraft will have significant speed, altitude, and survivability advantages that should expand the types of mission profiles they can fly, increase the reach of their sensors, and markedly reduce their risk of a shoot-down. In addition to reducing transit times in a large region such as the Pacific, flight at sustained supersonic speeds will allow ABMS effects to be delivered in a more responsive, agile fashion with a given number of aircraft.

Including supersonic battle management aircraft as part of the Air Force's ABMS would help the service fill its information, connectivity, and C2 capability shortfalls. It would provide a degree of redundancy in the ABMS construct by ensuring that command and control benefit from battle managers that can operate in critical areas of the battlespace. A battle management aircraft with an expanded operational envelope complements the information attributes that 5th generation aircraft like the F-22, F-35, and B-21 bring to the battlespace—especially highly contested areas where only they can safely operate. Add in next-generation unmanned sensor-shooters along with space-based sensors, and the ABMS vision for the future looks very strong but still allows for elements to be pulled away for lower-level contingencies or unexpected pop-up challenges.

At the end of the day, the success of the USAF's ABMS and JADC2 vision will come down to the system's ability to gather information, process it, and manage team

DOD definitions of C2

Command: The authority that a commander in the armed forces lawfully exercises over subordinates by virtue of rank or assignment.

Command and Control: The exercise of authority and direction by a properly designated commander over assigned and attached forces in the accomplishment of the mission.

Command and Control System: The facilities, equipment, communications, procedures, and personnel essential for a commander to plan, direct, and control operations of forces pursuant to the missions assigned.

Source: DOD Dictionary of Military and Associated Terms (as of 2021), p. 40.

WWI	Opening of WWII	Early WWII	Early Cold War	Mid-Cold War	Early 2000s to present day	ABMS and JADC2
Basic C2 measures	Early networked operations empowered by ground-based sensors, controllers, and radio communication	Aircraft-based sensors paired with ground-based sensors and associated C2 functions	Increasingly complex sensor networks, advanced control stations, and increasingly automated data transfer	The transition of the C2 controlling function to the sky	Distributed sensors, processing power and connectivity creating sensor-shooter complexes	Represent the next step in this evolution

Figure 1: Timeline of the changes in the relationships and interfaces between C2, ISR, and connectivity over the past 110 years.

Source: Mitchell Institute

members to best meet mission goals in a highly dynamic environment. These are the very same goals that have been in play since the early days of combat aviation. Technology is evolving the way in which these functions are achieved, but the fundamentals largely remain the same. The elements of information, connectivity, and C2 must be understood as separate and individual, albeit highly interrelated, mission assets and managed as such—with balance. Future success will demand embracing the proven components of the mission, while using advancements to take the function to a new level of effectiveness, efficiency, and resiliency.

Information, Connectivity, and C2—An Evolutionary History

Understanding the USAF's forward-looking ABMS and JADC2 vision is often best contextualized by recognizing the way in which information, connectivity, and C2 evolved throughout the history of aerospace power. This journey has seen an evolutionary set of approaches ranging from aircraft in the pioneering days of combat aviation roaming through the sky with minimal decision-quality information to overwhelming situational awareness and interconnectivity from the most forward edge of the battlespace and senior echelons of leadership.

Often the distinct entities of C2 and information (in the guise of intelligence, surveillance, and reconnaissance, or ISR)) are inappropriately mashed up as if they are one—C2ISR—and connectivity is generally assumed to be a silent part of this construct. These three components are, however, distinct features of modern military operations. They should not be considered as locked into a fixed, uniform model, since the rate of innovation and the demands of the modern operating environment will see their parameters rapidly evolve. Fundamentally, it all comes down to exploiting whatever method will maximize situational awareness to place mission assets at the right time and place to best net desired command objectives, while not projecting undue vulnerability. This requires insight, judgement, and decision making. Changes over time in the relationships and interfaces between C2, ISR, and connectivity have centered on the scale, scope, and speed of decision-making as technology advanced the art of the possible. This can best be summarized through seven main eras, as illustrated in the figure above.

Nothing illustrates the notion of mass making up for shortfalls in information, connectivity, and effective C2 than World War I combat aviation. Lacking any form of real-time intelligence regarding the position of enemy aircraft, fighter pilots had to rely on chance that they would visually spot their opponent in the sky. The term "dawn patrol" became synonymous with the idea of aircraft flying in search of the opposition. Even when pilots found their opponents, they lacked the means, such as radios, to call for friendly support. Commanders had to use large numbers of aerial forces to make up for their lack of knowledge regarding when and where to employ forces to attain their desired effects. The same was true for early bomber aircraft operations. As World War I combat aviator and future Royal Air Force (RAF) air commander John Slessor explained, "Our method and technique, even at the end of the war, were really primitive. In the early days there was not even such thing as a bombsight and bombing was done by the 'chuck and chance it' method."[13] An aircraft's value will always be compromised unless it is brought to bear at the right time in the right place. This left airmen largely reliant upon mass numbers to increase the odds that they would stumble upon their desired mission objectives.

Innovation: Rudimentary information networking. The need for better decision-making information was not lost upon airmen. In the years after WWI, they developed sensors, data fusion centers, and information networks to bring effective situational awareness and C2 to the sky.[14] This investment proved invaluable during WWII, most famously during the famed 1940 Battle of Britain. Stretched thin by austere interwar year budgets, the Royal Air Force possessed too few fighters and trained pilots to guard against German airstrikes through sheer numbers. The Royal Air Force had to ensure it could judiciously concentrate what few defensive assets it had at the right times and places to counter German air assaults. Radar stations along the southeastern British coastline detected German bomber formations as they crossed the English Channel.[15] Information fusion centers would interpret this data, combine it with additional reports provided by ground observes, map the German formation positions on a plotting board, and then order specific Royal Air Force fighter units to take to the sky. British aircraft aloft could readily be distinguished from enemy planes thanks to a special transponder known as "Identification Friend or Foe" (IFF). Able to distinguish RAF fighters from opposing aircraft, controllers would vector air defense assets to intercept German bombers with real-time position locations.[16] This enterprise was a far cry from the mass dawn patrols of World War I.

Ground-based electronic aids proved beneficial for bombing crews on both sides of the conflict, each of whom used radio-direction methods to guide their respective crews to assigned targets and signaled when to release their bombs over the aim point.[17] Absent such systems, British analysts confirmed that the vast majority of the RAF Bomber Command night strikes were dropping their bombs within a huge radius, upward of five miles of their intended targets.[18]

Innovation: Aircraft-based sensors. The third major iteration in aerial information gathering and C2 occurred when radar was installed onboard night fighter aircraft due to the need for further information fidelity than what could be delivered from ground-based stations alone—the beginnings of a weapons system. C2 centers vectored the defending fighters close to their targets, then aircraft-installed radar provided the last measure of guidance for attack.[19] A pilot's focus was now shaped by something other than his own eyes or ground-based sensors. This also yielded a nascent networked system, where ground capabilities, aircraft sensors, and the pilot as the fusion center collaborated to yield desired results. Initial applications were expanded by all sides during the war, including radar guiding bombers at night and overcast conditions.[20]

Innovation: The advent of ground-based sensor networks and early automation. As the United States found itself facing the Soviet Union in the early days of the Cold War, air defense systems

Figure 2: A U.S. Air Force EC-121D Warning Star aircraft conducting an Airborne Early Warning and Control mission over Thailand in 1972.
Photo: U.S. Air Force

yielded the fourth major development in aerial C2. Fast-moving threats traveling over large areas demanded rapid detection and tightly coordinated interception. Massive ground-based radar systems were built along the most likely routes that nuclear weapon-equipped Soviet bombers would take on their way to strike the United States. These radars flowed data to the Massachusetts Institute for Technology-developed semi-automatic ground environment (SAGE) air defense system, which included multiple centralized control facilities that processed the raw inputs into actionable information.[21] These centers then connected directly to air defense fighter units They comprised a far larger, faster, and more complex system than what existed in WWII. Automation increasingly took over functions previously executed by humans due to the need for speed and the number of complex calculations that had to take place in rapid order to yield time-relevant direction.

As part of this need for speed and precision, controllers sent information over automated data links. These electro-magnetic means to transfer radar plots, targeting information, and basic navigational inputs allowed for automated data transfer between distributed assets and largely supplanted radio voice communications. By the late 1950s, datalinks were so advanced that ground control units could connect to an air defense fighter's autopilot and direct it toward the targets.[22] The rapid processing of raw data to desired outputs gave air defense actors the benefit of decision speed—rapidly focusing available assets at the right time and place against very fast, dynamic adversaries. Manual systems of WWII, while similar in theory to their Cold War successors, could not function fast enough in continent-spanning scenarios involving jet speeds.[23]

Innovation: Transition to airborne C2. This value of rapid decision-making yielded a fifth era of C2 evolution. Aircraft like the Air Force's EC-121 Warning Star and the Navy's WF-2 Tracer integrated surveillance radar, communications, and a trained crew to provide flexible sensor coverage, onboard information fusion capabilities, and command and control guidance for air defense assets—aircraft now known as a command, control, intelligence, surveillance, and reconnaissance (C2ISR) systems.[24] These aircraft focused on expanding the CONUS defense net, placing sensors and C2 in remote areas, like over the ocean, or in forward operating locations. These systems were also deployable in times of war.

These C2ISR aircraft defined their new role under fire over Southeast Asia between 1965 and 1972. Air Force and Navy EC-121s were able to track both friendly and enemy aircraft thanks to their large radar apertures. Onboard technicians were able to interrogate and track enemy aircraft identification friend or foe transponders, which provided valuable position data. Linguists onboard the aircraft were also able to listen to enemy radio transmissions and provide further relevant data that could help U.S. fighter pilots successfully engage and destroy enemy MiGs.[25] Comparing this fused airborne C2ISR technology to older detection methods, an Air Force EC-121 crew member explained, "We were able to detect aircraft we had not previously seen. It was somewhat frightening to realize in the past there had been so many aircraft that we had not seen."[26]

This era also saw the development of a multi-domain C2 effort between aircraft and Navy ships in the Tonkin Gulf gathering, fusing, and passing along important threat data.[27] At Nakhon Phanom Air Base in Thailand, the United States operated a C2 system known as "Tea Ball," which could process mass data flows of signals intelligence, electronic emissions data, and radar intercepts. It could then combine them to provide a real-time picture that helped inform command and control decisions in the unfolding air war.[28]

Nor was all the decision-making progress occurring within C2ISR-specific systems. Combat aircraft like the F-4 Phantom, A-6 Intruder, and later the F-111 Aardvark, F-15 Eagle, and F-14 Tomcat were defined by their increased use of sophisticated onboard sensors and computing power.[29] This technology, paired with a broader C2ISR enterprise, saw aircrews able to execute far more complex, demanding missions with a higher success rate.

However, information's ascent in the battlespace had a downside. The power of the sensor and C2 construct was increasing markedly, but data was being thrown at the air crews in a highly haphazard mode. Federated systems totally separated from one another in their function and transmission were literally drowning air crews in too much data, flowed to them through disjointed audio and primitive visual means. There is simply only so much data that a human crew member can absorb, process, and act upon in a concurrent manner. Col Richard Borowski, an Air Force F-4 Phantom pilot and veteran of 151 combat missions over Vietnam, explained the challenge he confronted with data saturation on a mission that nearly cost him his life:

> *There were a lot of things going on. The radar warning equipment was letting us know that enemy missiles were being launched against us. I had intelligence coming from an agency in real time that was telling us that MiGs were coming up from behind us that were going to attack. We had ground control from a carrier in the Tonkin Gulf telling us where the MiGs were approximately in relation to us. We were listening to the people that we were escorting. There were other people that were suppressing AAA and the SAMs—all on the same frequency or on various frequencies that we were listening to. I could hear the growl from my air-to-air missiles—the heat seekers had a distinctive sound…and of course all the noise coming from the radar warning equipment. As it happened, a MiG came up from behind me, and my wingman saw him and tried to warn me of the MiG. I never heard the warning,*

and I saw a missile go by—which was his first shot, which he missed. I tried to turn out of the way…the second missile shot only managed to damage my aircraft, and I brought the airplane back. But I never heard my wingman calling me trying to tell me there was a MiG behind me. When I got back to base, I listened to the tape of the mission, and clear as day, he told me that a MiG was there and what I should do to avoid the attack. I didn't hear it. I was totally saturated.[30]

Borowski was not alone in dealing with this deluge of data. Famed WWII ace and commander of the 8th Tactical Fighter Wing during Vietnam, Brig Gen Robin Olds, described a similar challenge and an improvised means of managing the data flow:

> *Going up the Red River…we had a procedure where we started turning off things like the detection gear for the SAMs. It made noises, it bothered you. We turned off guard channel because there was always someone screaming in an emergency. We'd turn off the growl of the sidewinders. I'd usually put the kid in the back seat [weapons system operator] on cold mic so I could not hear him…and so I'd turn off all the noise so I could concentrate on the matter at hand.*[31]

There was only so much someone could hear, view, process, and competently act upon at a given moment. Data could only be useful if it could readily be transformed into actionable knowledge.

Recognizing this problem, the Air Force and Navy spent the years after Vietnam fielding next-generation C2ISR aircraft that could focus more on processing flows of data such that aircrew were only presented with what they needed to know to meet commander's intent. The resulting aircraft included the Air Force's E-3 AWACS and the Navy's E-2 Hawkeye.[32] Then-Commander of Air Force Tactical Air Command Gen Robert Dixon explained the value afforded by a system like AWACS:

> *The extension of the surveillance horizons for warning and control with survivability, far beyond the limits of ground-based systems, through the employment of the E-3, can provide civil and military leaders, as well as battle managers, with a never-before-available view of the battle arena—potential or actual—and on a real-time basis. For the first time in history a man can have an instant, real, certain view of air and, if desired, ground and sea operations, before or during a conflict.*[33]

The value of this knowledge is essential, for as Dixon further elaborated, "The perfect vision of potentially hostile air activity will enable a commander to position his forces with economy and mass at the proper time to deter, or to fight. We will have time to think, reason, and act, rather than just react."[34] Data, transformed to information and harnessed as actionable knowledge, was the key to making the best use of available forces to meet mission intent.

The E-3 and the E-2 were not the only new information-focused assets developed in the years after Vietnam. The ground-focused portion of this network was constructed in the late 1980s and early 1990s with the E-8 Joint Surveillance Target Attack Radar System (JSTARS)—a plane carrying a powerful ground-focused radar able to track vehicles, ships, and other items of interest; analyze data onboard; and pass key points of interest to individuals through the strategic, operational, and tactical construct.[35] Just to give an idea regarding the power of these systems, the E-8's radar can view 19,000 square miles on a given mission, with its radar able to detect targets at over 120 miles.[36]

The Air Force complemented these two systems with ground-based control systems, which combine sensors and links to airborne C2ISR aircraft for an expanded vantage. These assets provide situational awareness and guidance in regions where forces will remain in place over an extended period and access is allowed. They are particularly useful in rear echelon operating locations as a layered part of the C2 enterprise. In many ways, they are like an AWACS stationed on the ground.

Beyond the AWACS, JSTARS, and ground control stations in the C2 hierarchy is a senior operational command-level center, now known as the Air Operations Center (AOC), which executes mission planning days in advance and provides real-time inputs when necessary for live events. It is the senior element of the Air Force's Theater Air Control System (TACS), and it is where the Commander, Air Force Forces (COMAFFOR) provides the Joint Forces Air Component Commander (JFACC) a facility for planning and executing theater-wide aerospace forces. When the COMAFFOR is also the JFACC, the AOC is also the Joint Air Operations Center (JAOC). In cases of Allied or Coalition (multinational) operations, the AOC is also a Combined Aerospace Operations Center (CAOC).[37]

The systems that grew out of Vietnam offered significant advancements, but still ran into challenges in 1991 during Operation Desert Storm. The command center—then known as the Tactical Air Control Center (TACC)—was where the Desert Storm air campaign was orchestrated. Multiple ground-based C2 systems, combined with aerial C2ISR nodes like AWACS and JSTARS who also provided real-time guidance at the tactical and operational level of command, fed information to the TACC. Individual combat aircraft also used their onboard sensors and processing power to maintain their situational awareness.

The C2 processes and procedures in place in the TACC at the time were out of date and not able to keep up with the rapid pace of the conflict. This necessitated ad hoc procedures and workarounds to optimize the air campaign. Information was still hard to access, with much of it locked away from operational and tactical users—for example, timely space imagery. These actors at the operational and tactical levels lacked tasking authority over relevant intelligence satellites due to a bureaucratic decision process designed to support possible Cold War-era engagements such as Warsaw Pact forces invading Western Europe through the Fulda Gap. Dynamic adjustments based upon evolving mission requirements and information sharing were not prioritized in this construct. Most missions were still executed based on pre-planned taskings, appointed times, and lanes of engagement. Real-time, dynamic tasking was rare.

Innovation: Transition to distributed sensor-shooter complexes. Recognizing the crucial importance of command and control during fast-paced operations like Desert Storm, the Air Force embarked on a modernization of its C2 structures after Desert Storm and throughout the 1990s. In the early 2000s the Air and Space

Figure 3: A U.S. Air Force E-3 of the 963rd Airborne Air Control Squadron in 2012.
Photo: U.S. Air Force

Operations Center (AOC) was given its own designation, AN/USQ-163 Falconer, as a weapon system unto itself.[38] Advanced space-based sensors and those on remotely piloted aircraft (RPA) also gradually entered this layered system thanks to technology and associated concepts of operation that transitioned these feeds past the intelligence community to the operational realm. To this latter development, the introduction of persistent overwatch provided by armed, sensor-equipped, and highly connected RPA resulted in a truly unified, integrated sensor-shooter construct. This was a fundamental game changer in the evolution of the interplay between information, connectivity, and C2.

In the aftermath of the attacks of September 11, 2001, a different kind of war against terrorists and a range of non-state actors drove new information, connectivity, and C2 demands. These counterterrorism operations introduced two divergent trends: the desire to target fleeting aim points while doing everything possible to limit collateral damage. This not only drove asset micromanagement but ushered in a shift in traditional Air Force C2 doctrine from centralized control/decentralized execution to a practice of centralized control/centralized execution. Not making the wrong decision became the overriding goal.

This was largely realized by the sixth major development in information, connectivity, and C2. Technological advances in the field of networked connectivity, high-fidelity sensors, persistence in overwatch by RPA, and huge gains in computing power saw seismic advances in combat edge situational awareness and decision-making. These technologies also helped blur the different levels of command, since they enabled senior leaders to "reach into" a cockpit or watch what was going on in the battlespace in real-time and direct decisions at the most tactical levels. This centralization slowed the pace of C2 as actors sought to maximize information to guide flawless, nearly immaculate, kinetic operations. Striving for perfection proved a far different and more difficult goal to achieve than striving to win.

Poor force coordination resulting from anachronistic organizational procedures resident in the AN/USQ-163 Falconer AOCs was another trend. For instance, the AOC system used separate planning procedures for ISR aircraft and strike aircraft. Segregated planning for these two capabilities yielded missed opportunities and mission suboptimization at the very moment technology allowed for the notion of sensor-shooter aircraft and highly integrated teaming. In other words, "ISR" aircraft could perform strike missions, and "strike" aircraft could perform ISR, but the established planning procedures did not allow for this kind of tasking, and that led to missed coordination and employment opportunities.[39] According to one Air Force C2 professional, missed opportunities created by suboptimized C2 were both routine and frustrating:

> *A C-130 might air-drop supplies to a drop zone plagued by small-arms anti-aircraft fire. The*

> *drop might occur immediately beneath an MQ-1 Predator orbit, but the Predator crew would not know that the airdrop is planned, much less scan for threats to the C-130—unless the supported unit happens to task it to do so. Simultaneously, one regional command over, an F-16 provides armed reconnaissance along a route that friendly forces will patrol the following day, oblivious to the fact that an MC-12—in an overlapping orbit—has found and fixed a high-value target, hoping that a strike asset arrives in the area before collateral concerns preclude an attack. An HH-60 takes fire during a casualty evacuation mission, not knowing that a Sandy-qualified A-10 is in the next kill box. These are fundamental breakdowns.*[40]

The cause of these kinds of breakdowns—that persist today—is the result of the design of the current Falconer air and space operations center. This design was built around separate tasking procedures for ISR that use a system known as the Planning Tool for Resource Integration, Synchronization, and Management (PRISM), and force applications that use the TBMCS.[41] It reflects an outdated paradigm of mission execution that must be fixed in ABMS and JADC2. U.S. forces cannot afford to operate like this in future battlespaces where they will be stretched to the limit from both a capacity and capabilities perspective. The risk of high force attrition adds further stress to the situation. The planning and tasking process should be merged to ensure a unified and optimized effort regardless of aircraft categorization. This reflects the reality of an integrated, collaborative sensor-shooter contract. Technology has rendered the traditional AOC organizational structure obsolete. It requires a change to a consolidated planning and tasking process for all aircraft—and at some point, spacecraft as well.

In reviewing this history of change and innovations, it is important to view them through the lens of the three core elements in play—information, connectivity, and C2. Advancements in elements like processing power radically impacted the speed and scale of the enterprise, but the core elements remained the same. That strongly suggests building tomorrow's system will continue to demand equal and integrated developmental effort between these three facets.

Successful force employment is highly reliant upon C2 appropriately tiered throughout the system to best meet desired objectives in a rapidly evolving set of circumstances. To achieve this, analyzing, planning, and designing force employment should occur at the operational level through the creation of master air attack plans and their administrative transmission documents—the air tasking orders—at the air operations center. The AOC should then guide assets real time with the execution elements of the theater air control system, ensuring the commander's intent is maintained. Finally, combat forces should make the most of their situational awareness and engage as best possible, understanding that intent. As the Vietnam conflict experience revealed, performance will degrade if forward actors are pummeled with too many disparate information inputs. It is crucial to filter information to ensure each actor receives what is needed, but not what is irrelevant and distracting. However, part of this involves drawing lines, or the system will slow with too many actors bogging down the process, as was clear from Afghanistan and Iraq. It may also grow too fragile if connectivity between all the actors cannot be maintained in a constant, assured means—something of increasing concern given future high-end threats. It is no longer about deconfliction, modern reality demands collaborative, responsive integration. These lessons have stood the test of time because smart teamwork yields better mission results.

ABMS represents the next step in this evolution. Throughout history, levels of available information, connectivity, and C2 played a crucial role in shaping military operational concepts and strategies. A force that lacks these attributes requires the use of far more mass to achieve operational objectives. In other words, it is a process involving levels of certainty—the more commanders know, the better they can focus their efforts to achieve their objectives.

Next Step in the Evolution of Information, Connectivity, and C2: ABMS and JADC2

The United States now finds itself in a "back to the future" type scenario as peer competitors define battlespace priorities. Instead of the permissive environments that airmen experienced in the skies over Afghanistan and Iraq, they must be prepared for incredibly complex, fast, dangerous, and dynamic operations against far more advanced adversaries. Their success will be defined by their ability to conduct operations concurrently throughout the battlespace in a coordinated fashion that out-paces the adversary. Opponents will be targeting every element that is critical to generating U.S. combat airpower—U.S. theater operating bases, mission aircraft, logistics, and information networks. To this latter point, top adversaries now consider denying information, connectivity, and C2 as their primary military objective. As the Department of Defense's 2020 report on *The Military and Security Developments Involving the People's Republic of China* highlights, "China's leaders [think] that achieving information dominance and denying adversaries the use of the electromagnetic spectrum is necessary to seize and maintain the strategic initiative in a conflict."[42]

This brings us to the current state of play. The Air Force recognizes these challenges and has long been aware of its shortcomings. This is a primary reason it is changing its current approach to information, connectivity, and C2 to a far different model—ABMS and JADC2.

Today's ABMS and JADC2 vision largely ties back to the middle of the 2000s, when Air Force leaders were increasingly aware of the airframe age of the E-8 JSTARS. This triggered a broader set of considerations as replacement options were reviewed. While these aircraft were fielded in the inventory in the late 1980s and early 1990s, the JSTARS airframes were originally constructed in the 1960s. Long-term serviceability was a rising concern. The Air Force had already pursued one effort to recapitalize the aircraft and its associated mission systems through the E-10 program, which was later canceled. During the same timeframe, technologies were also rapidly changing. As early as 2008, Lt Gen Deptula, then the Air Force chief of ISR, initiated efforts to look at different means of hosting ground moving target indicator radars (GMTI) beyond simply putting it on an updated replacement aircraft. Later, he consolidated his ideas into a description of a concept that connected sensors, shooters, and effectors into a notion of a "combat cloud," that was the precursor to what became ABMS and JADC2.[43]

In 2010 the Air Force launched an analysis of alternatives (AOA) regarding how to best execute the aerial C2ISR mission with the JSTARS GMTI.[44] This eventually evolved into a requirement for a new manned aircraft, with the C2 crew and the ISR GMTI sensor co-located onboard the same airframe in a method like the E-8. The main areas for growth were newer sensors, processing power, connectivity, and automation that would offset some of the air battle manager crew.[45] Industry offerings took shape in the form of large business jet type aircraft carrying an onboard GMTI sensor and air battle management crew.[46]

In 2017, Air Force leadership signaled they were considering a different vector to recapitalize the JSTARS system. Air Combat Command Commander General Mike Holmes explained, "The world is changing; the threats are changing. We are going to take a look at all the threats we are facing."[47] Service leaders increasingly grew concerned that a large, sensor emitting aircraft like the JSTARS, or its proposed replacements, were not going to survive in the anticipated high-end threat environments surrounding adversaries like China or Russia. To this end, the Air Force harnessed an AOA originally focused on AWACS recapitalization to look at the broader C2 and ISR mission set. This effort was branded the Advanced Battle Management System.[48]

With the submission of the Air Force's FY 2019 budget request, the service leaders officially terminated its planned JSTARS recapitalization effort and proposed the networked ABMS vision as the preferred solution.[49] Budget justification documents from this decision explained the essence of the new approach:

> *The Advanced Battle Management System (ABMS) is a family of systems construct that provides battle management and command and control capability by networking, ingesting, fusing, and prioritizing data from disaggregated sensors. ABMS is not a single program of record but a capability that is provided by multiple integrated systems and programs and will be horizontally managed by the ABMS Architect. ABMS will develop sensors, battle management and command and control systems, and communications through a three phased strategy.*[50]

The first ABMS phase is designed to harness existing programs of record to net desired effects. Phases two and three are supposed to use increasingly disaggregated approaches that will largely rely on new technologies—the vast majority of which remain highly classified. This does not just impact the E-8; as then-Assistant Secretary of the Air Force for Acquisition, Technology, and Logistics Dr. Will Roper explained in congressional testimony, "ABMS will be able to perform the mission sets associated with both the JSTARS and AWACS platforms and possibly assume other roles of the Theater Air Control System."[51]

This leaves the ABMS networked approach as the current program of record that will eventually replace aircraft like the E-3 AWACS and E-8 JSTARS. It is the ecosystem of sensors, processing power, fusion, artificial intelligence, and data transfer networks that will empower modern C2: a concept that DOD now calls Joint All-Domain Command and Control.[52] Words matter when it comes to military concepts, and the phrase "joint all-domain" refers to the notion of mission systems partnering real-time in a domain-agnostic manner. The composition of ABMS and JADC2 teams will be based on creating the best partnerships at given times and places to achieve desired effects better than what any single asset could do individually. Data gathered by systems in one domain will be processed and drive actions of actors elsewhere in the system if those actors are in a better time and place to net the desired goal. As one Air Force document explains, "Joint all-domain command and control connects distributed sensors, shooters and data from and in all domains to all forces to enable distributed mission command at the scale, tempo, and level to accomplish commander's intent—agnostic to domains, platforms, and functional lanes."[53] ABMS is the technical means by which that partnering occurs.

The scale and scope of this effort is a whole-of-Air Force enterprise that extends far past recapitalizing a given aircraft like JSTARS or AWACS. As Dr. Will Roper explained, "What we want to do is ensure machine-to-machine data transfers occur everywhere, so that if any sensor sees something, that data is available to a shooter anywhere without impediments."[54] Air Force ABMS Chief Architect Preston Dunlap believes this effort really comes down to "making these platforms better than they would be individually through integration."[55]

A short scenario can help illustrate the Air Force's vision. ABMS could give an F-35 and a B-21 that expended their weapon payloads the ability to collaboratively provide high fidelity target aim point information to a Navy or allied ship located offshore. The combined actions of these geographically separated aircraft brought together as a team by the ABMS network could enable the ship to launch its weapons at one or multiple targets. By partnering, these very different weapon systems could create effects in the battlespace that exceed what any one of them could have achieved alone. It all comes down to gathering disparate flows of information, fusing them into a whole that reveals more knowledge of the battlespace than can be provided by any individual source, and tasking effectors that can meet the desired task objectives. Of course, this is just one vignette among many potential combinations enabled by ABMS. There will be times when multiple effectors from different platforms might combine to yield a single result. To this point, an F-35 could jam enemy defenses located around a target, while a B-21 launches a munition using information provided by space-based sensors to successfully penetrate the disrupted defenses and impact the target with great precision. This is an example of an advanced level of coordination made possible by ABMS that will yield major new advantages in a peer conflict. As former Air Force Chief of Staff General Goldfein explained on the ABMS construct enabling the future force, "If we connect them, we're going to have options available that we can throw at the adversary that today are not available."

Fifth-Generation Aircraft and C2ISR for Modern Combat

Fifth-generation combat aircraft are key actors in the new operating environment. The F-22, F-35, and eventually the B-21 harness stealth technology and electronic means of survivability to bring their sensor suites, processing power, and ability to collaboratively engage with other combat systems behind enemy lines.

Unlike the Vietnam-era fighters that saw crews bombarded with too much disparate information, 5th generation processing uses technology to transform mass quantities of data gathered both onboard and offboard the aircraft to decision quality information. They can observe things and make operational-level assessments—once the sole purview of large scale C2ISR. There are times when a 5th generation aircraft can actually serve as a C2 and ISR node.

The limiting factor in this equation is how much information and C2 duties a combat pilot may be able to handle amidst primary mission responsibilities, avoiding threats, and the rapid decision-making that occurs in a highly dynamic environment.

While the technology in this enterprise is new, the overarching intent and macro construct is time-tested. The Battle of Britain had its network of sensors and communications systems. C2 experts could direct fighter pilots as the kinetic actualizers of their directives. Fighters could team through radio communications and practiced tactics. ABMS and JADC2 expands this model in scale, scope, and speed. However, the benefits remain the same, as is the basic approach of making the best use of available assets to achieve information and decision superiority. The ability for machines to share data automatically without human engagement, to seamlessly collaborate, and to net objectives together is simply the next phase of growth in the construct thanks to advances in technology. Given the realities of a force stretched thin amidst a burgeoning threat environment, the Air Force must pursue this approach.

With ABMS standing as the technical means of information exchange—the electronic infrastructure through which the data flows—and JADC2 serving as the higher echelon tasking, aligning commander's intent to operational and tactical level actions, some key questions emerge:

1. How are massive amounts of data gathered by such a large enterprise system being filtered and fused productively to prevent saturation; and
2. Who or what is exercising C2?

Answering these questions will prove vital to delivering a set of capabilities and an operating construct that will function in an operationally responsive, relevant, and resilient fashion. This is what will make the ABMS program a success instead of a simple update of a technology investment program like TBMCS. The answers would also inform members of Congress who seek to better understand ABMS. As one House Armed Services Committee staffer explained, "Over the past two and half to three years since it was first rolled out, the concept of what ABMS was supposed to be, has changed significantly. The committee is still looking for some additional information and better clarity on where all that money is intended to go."[56]

One thing is certain, however—this journey toward ABMS and JADC2 will not succeed if the dominant focus is only on improving connectivity. History has illustrated that mass information flows do not yield improved decision scenarios. As a 1999 RAND C2 study highlighted, "In the age of abundant, almost limitless, information and communications capabilities, decision makers are increasingly faced with the problem of too much information, rather than too little." RAND's report points out the obvious solution: "Understanding what information is most essential for decision-making—**so that the information being communicated, processed, or displayed can be bounded** [emphasis added]—is now a major issue in the design of computer-aided decision support systems."[57] The problem of too much information is similar to the problem faced by pilots in the Vietnam conflict. It also occurred in the 2000s and 2010s when RPAs gathered data at rates never seen before in the history of warfare. Their ability to collect information scaled far past the established means to effectively harness the resulting information. It led to meltdowns when it came to the processing, exploitation, and dissemination (PED) process. At one point, Airmen in the PED field saw a 5,000 percent increase in the amount of sensor data produced.[58] The chief of Air Force ISR at the time coined the phrase, "we are swimming in sensors, so we need to ensure that we don't drown in data."[59] Knowing how to recognize what mattered, make sense of it through informed analysis, fuse it with other important feeds, and pass actionable knowledge to the relevant actors in a timely fashion proved exceedingly difficult. DOD's initial response was to simply throw manpower at the problem, but that solution proved cumbersome, costly, and too slow relative to meeting real-time mission demands. Efforts to improve the process through technology has since helped, but the growth of data still far outpaces the means available to transform it to actionable information.

This experience stands as a warning to ABMS and JADC2 architects. The challenge of processing, filtering, and directing information flows appropriately aligned to a broader C2 vision across the battlespace will escalate to levels previously unimaginable given the number of nodes that will comprise the system. In the past, data flows were limited simply because there were not that many collectors and stovepipes limited the effective reach of the information. Now, anyone will have the potential to see anything, which would be like watching all your cable TV stations at once. Theoretically there would be a lot of information in play, but realistically it would be unusable. ABMS and JADC2 must include an effective automated means that understands which platform, unit, or individual in the battlespace needs what information, when, and for how long.

Fifth-generation technologies are part of the solution. Modern technology, especially 5th generation processing, fusion, and displays, have made significant progress toward this end—especially when it comes to transforming mass data into actionable information. However, those systems are still operating in a defined regional context. Modern airmen experienced in 5th generation aircraft employment also possess a vastly superior view of the battlespace surrounding them that was previously reserved only for AWACS or JSTARS aircraft. Their onboard sensors, their ability to automatically fuse offboard data into their organic situational display, and their ability to constantly assess the environment for pop-up threats is incredible.

However, these airmen are also flying very fast in contested airspace juggling a myriad of mission tasks. Their focus is on a specific mission within a bounded geographic space. They are often not able to look at the operation as a holistic enterprise. Pilots must also focus their attention on controlling their aircraft, not just dealing with a large influx of fused, actionable information. To this point, a 5th generation combat force will still need air battle managers that assimilate battlespace data and call the plays similar to football quarterbacks. As the RAND C2 report explained that "command is both an organizational function and a cognitive function, and that technology, by itself, is not a panacea."[60]

AI, automation, and machine learning are also part of the solution. ABMS and JADC2 will expand the information net considerably. Machine learning, automation, and artificial intelligence will no doubt assist further in this process, but there must be a deliberate plan in place to ensure that concepts of operation are able to scale to a level that allow for the full exploitation of the potential that new technologies offer. This ties to the notion of C2 and appropriately tiered decision makers. Success in warfare depends upon translating the commander's intent into operational and tactical actions across the battlespace. A combat action against a peer adversary could see thousands of major movements and tens of thousands of smaller movements occurring each day. The Air Force has not had to think on this scale and at the inherent concurrency of decision-making needed for peer-on-peer conflict scenarios since the end of the Cold War. Counterinsurgency operations are far smaller, slower, and less intense, given political and operational constraints, compared to a major war where thousands of actions will be executed every single day and rear-echelon locations will be under attack. Additionally, during post-9/11 counterterrorism and counterinsurgency operations, U.S. forces could almost always count on total information connectivity, which encouraged strategic reach down into operational and tactical situations on a real-time basis. There is no way large-scale peer adversary scenarios would ever allow for this sort of an approach. Events will move too fast, they will be too complex, and connectivity will be under constant assault.

AI, automation, and machine processing can transform a certain tier of data into immediately actionable information that is relevant and value-added in a frontline cockpit. Consider a threat warning detecting a surface-to-air missile site and suggesting an alternate flight path. The automated systems could also track how a mission is progressing and prioritize mission objectives based upon real-time developments. For example, if targeting a command center was the overarching objective of the day's activities, and the strike package originally tasked with this mission was aborted on the way to the target, this action could be detected. The responsibility for the strike could be reallocated to another set of aircraft with the appropriate mission attributes, physical proximity, and fuel status to execute the mission.

AI, automation, and machine learning will not replace human battle managers. The effective projection of airpower in alignment with command intent and broader political and military objectives is not a mechanical act tied to a predetermined set of decisions. It involves juggling numerus factors—many far from clear and exercising best judgement in rapid order. Things get tricky when lead-in assumptions prove incorrect and mission conditions are far different than what was anticipated. Although automation will narrow down the pairing process and aid decision-making, at some point, an appropriately tiered layer of command must ensure actions taken will result in the best desired effect to achieve a commander's intent. According to one air battle manager commander, "Arguably, we have developed the most powerful ISR capabilities in the history of the world. Additionally, 5th generation aircraft present their own source of SA [situational awareness] in new ways. Without the unifying force that is C2, these amazing technical advances may realize only individual success or localized advantage rather than broader operational-level advances."[61]

Nor is this thinking wholly discordant from the vector taken by Air Force leaders. Dr. Will Roper recently explained, "I think leading [battlespace] edge systems are going to have to be quarterbacked by people that are standing back ready to make the calls."[62] These C2 actors will need to be relatively forward in the battlespace, given that connectivity often grows more fragile with distance. This means being onboard a mission aircraft equipped with sensors, processing power, and connectivity. Basic physics dictates that there will be times when physical proximity to the battlespace will yield communicative advantages. This does not mean that the notions of C2 and ISR must be indivisibly linked. If active sensing poses too much risk, air battle managers can rely on offboard data sources gathered from the broader network. That is the entire point of ABMS. C2 and ISR were previously hard-linked due to the technological requirements of a past era. Co-location of C2 and ISR has advantages in certain circumstances because that hard-wired connection is extremely difficult for an enemy to defeat, which affords broader mission resiliency, but it is no longer the sole way the system must function.

The value that a tiered approach to the battlespace presents also speaks to the importance of taking a proactive risk mitigating strategy when it comes to relying on new forms of technology. ABMS faces risk in this area because the program demands so much innovation and will be employed against adversaries seeking to defeat it in the no-holds-barred environment of combat. A 2020 GAO report assessing the program highlighted this risk: "Since the Air Force has not identified what the technology needs for ABMS are, it cannot yet determine if those technologies are mature or will be mature when needed." The assessment further observed, "We have previously found that starting development without first identifying and assessing the maturity of technologies increases the likelihood that those technologies are not mature when needed, which often results in cost overruns and schedule delays."[63] Risk mitigation will be crucial if ABMS and the broader JADC2 initiatives are to succeed. Too many aggressive technological leaps demanding high levels of assured performance invite ultimate program failure. A middle path is a far more dependable approach, balancing innovation with proven methods of mission execution.

There is no question that gathering, processing, fusing, and distributing massive amounts of information to support networked teaming operations will require machine-derived assistance in the form of artificial intelligence, automation, and machine learning. Our adversaries are also pursing these advantages, and whomever holds the edge in them will own an extremely important competitive advantage. The RPA data flood is a cautionary experience in this regard. Tackling that tsunami of information with manual means alone was simply unworkable. ABMS promises data flows exponentially higher.

However, while technology must be part of the solution, going all-in on AI, automation, and machine learning does not mean abandoning proven methods that offer redundancies and complementary strengths. As Dr. Roper further elaborated, "We are not ready to pull people out of the fight, we are not ready to AI everything. R2D2 is great in the movies, but R2D2 in the real world gets really confused when an adversary is trying to mess with the data they are ingesting to make decisions."[64] To this point, proof of AI's fallibility unexpectedly emerged with the onset of the COVID-19 crisis. AI algorithms were written based upon human behavior patterns nearly everyone thought were immutable norms. Lockdown orders injected disruptions few could have imagined, with the net result seeing AI confused in a world that no longer conformed to its programmed assumptions. Just ask anyone from the retail sector who used AI to assist managing inventory—sales figures often departed expected patterns with wide variance.[65]

If the United States is overly reliant on AI and machine learning without prudent oversight and redundancies, adversaries will be incentivized to pursue operational concepts and tactics that undermine algorithms through embracing the unexpected. Human C2 engagement with professionals well-versed in resolving challenges in dynamic situations helps manage that risk. Air battle managers appropriately positioned within the battlespace will be a key part of this redundant, complementary enterprise. Raw technology does not equate to the realization of C2. As one airman explained, "[Individuals] are led to believe that the meaning of C2 is maintaining networks in the cyber age. Yet, in terms of grasping C2, networks do not explain that concept any more than missiles explain air superiority or bombs define global strike."[66]

Finally, there is another important reality to balance—one not making a lot of headlines at present. While China is certainly DOD's pacing threat and Russia is not too far behind, America will undoubtedly engage in numerous operations in far fewer threating regions of the world where mid-tier and low-end threats are the predominant concern. While America focuses to prepare for the most significant and likely threats, the reality is that global circumstances past its control often throw unanticipated challenges into play that must be addressed. This demands options that are rapidly deployable, sustainable, and affordable but do not degrade capabilities and capacity that are necessary for high-end operations tied to core U.S. interests. In many ways, this is where the proven forms of C2ISR in the forms of AWACS and JSTARS excel. They can project specific mission effects into certain geographic regions in rapid order. Their presence can be sustained for an extended period, allies and partners can easily integrate into their C2 construct, and their operating paradigm does not break the bank.

ABMS either needs to meet these same criteria, or the Air Force needs to pursue a complementary C2ISR system that will add value across the full operational spectrum—from high-end operations to lower-tier engagements. This involves the core attributes of information-gathering sensors, connectivity, and C2. Mission-based affordability and practicality are real things. It is one thing to rely on a highly disaggregated, high-end network of sensing and processing nodes in a major theater conflict, but it is likely imprudent against lower-tier threats given that such assets are normally in limited supply and their readiness must be guarded for major conflicts. There is utility in considering a "daily driver" plan-b force. An integrated mission aircraft able to take off and self-deploy anywhere in the world in a matter of hours affords unique advantages.

Above all, the solutions pursued must be flexible and adaptable. They must be oriented on solving problems in the rapid, complex combat environment. It is about speeding decisions, bringing order to a complex set of events, and producing desired effects. As one Air Force officer with a deep bench of experience highlighted, "The critical minimum infrastructure of a holistic C2 system cannot be determined generically or agnostically; rather, it is entirely dependent upon the commander's requirements, given specific missions to accomplish under specific conditions."[67] The key to that sort of flexibility demands a range of tools that have varying levels of capability, adaptability, and cost sensitivity.

A Forward Vector for Information, Connectivity, and C2

The ABMS and JADC2 constructs under development by the Air Force make a lot of sense. Information has always been the key to fighting and winning, especially when mass was not a guaranteed option. Advances in technology also promise to help manage the onslaught of unfiltered data, ensuring that AI, automation, and machine learning help add decision clarity to the process. That said, there appears to be a void in the new construct—the operating location for

Figure 4: Various supersonic aircraft design concepts, like Boom's XB-1 supersonic demonstrator, embody the technologies that could prove useful for the Air Force's C2ISR mission.
Photo: Courtesy of Boom

human-executed C2, a job traditionally executed by air battle managers.

The entire premise for moving from large scale C2ISR platforms is based on the fact they are no longer survivable in regions where threats are pronounced. Protecting aircrews, while seeking alternate means of secure desired effects, is both responsible and smart. However, a place still exists for a manned C2 platform given the need for appropriately tiered C2 actors in the battlespace, the connectivity advantages of executing C2 in a proximate location to forward-employed forces, the desire to have fallback options should primary solutions fail, and the need for a force to swing elsewhere in the world, a place still exists for a manned C2 platform. As one Air Force C2 expert explained, "By means of mobility, airborne C2 offers range, reach and adaptability—coupled with unique communications and surveillance feeds unmatched from space—to provide in situ problem solvers who align understanding of commander's intent to the chaos of actual conflict."[68]

On the one hand, technologies like the proven E-7 Wedgetail aircraft that Australia and Great Britain are procuring are readily available and have been used repeatedly with a high degree of success in exercises with U.S. forces. These aircraft certainly meet the mission functionality and affordability criteria for medium- and low-end operations. The Air Force could also look at extending the life of its JSTARS and AWACS aircraft. However, concerns regarding their survivability against high-end actors are legitimate.

This points to the potential afforded by a new class of aircraft—large scale supersonic aircraft under development in the commercial sector.[69] The U.S. Department of Defense has already signaled interest in these aircraft for their senior leader transport fleet.[70] However, mission-wise, they could also fulfill a role in the realm of C2ISR. In fact, language in the FY 2021 NDAA instructs the Air Force to investigate this application.

The advantages are straightforward and speak to many of the Air Force's concerns regarding the long-term viability of its legacy C2ISR fleet. From an operational perspective, supersonic cruise at extended range, a capability all of the proposed jets in this class purport to achieve by virtue of their civil mission goals, would allow a C2ISR aircraft of this class to deploy with utmost speed and rapidly cover vast operational ranges. This would allow more time on station by spending far less time transiting to and from basing locations. This would also allow the use of bases far removed from the reach of enemy offensive systems, while not placing further demands on finite ramps in key operational centers of gravity. Locations like Anderson Air Force Base in Guam have limited room.

This risk reduction does not simply tie to basing. An aircraft operating at supersonic speeds adds complexity to an adversary's ground-to-air and air-to-air defenses. Add this to the high altitude at which these aircraft operate—over 60,000 feet—and the size of the effective enemy defensive threat rings reduce markedly. The threats do not go away, but they are far smaller compared to what an airframe derived from a subsonic airliner would face. Sensors operated at high altitude can also see further, which is basic physics regarding sightlines.

On top of these mission profile advantages, these new aircraft could be designed with open mission systems and modular mission payloads. For a C2ISR aircraft to be truly useful, the ability to rapidly modernize mission systems is essential. The ability to swap sensors, processors, and other mission systems in rapid fashion in response to specific operational goals would also prove exceedingly useful. What if a jet knew it was going to face certain threats and be asked to gather specific types of information on a given sortie? Modularity could see mission systems specifically customized to meet those goals. An entirely different suite of systems could be uploaded for the next task. This approach is not science fiction; it has already been harnessed by aircraft like the U-28, which afford tremendous mission modularity. If a new modular system works well, then it could be scaled. If it failed to meet expectations, simply pull it off and go back to proven options—or try something else. Either way, the aircraft's functionality is not held hostage to incredibly complex, costly upgrades in the traditional model.

Finally, there is still tremendous utility to the C2ISR integrated model. Not only does this afford a rapidly deployable mission package for lower-tier operations but co-locating sensors with C2 experts mitigates the risk posed by an entirely disaggregated sensor-C2 construct. Hard wires and optical fibers connecting sensors to C2 workstations are very difficult to defeat. This is not to say that the mesh network of distributed systems proposed by the Air Force is a bad concept. In fact, certain threat scenarios might see the aircraft turn off its onboard sensors and execute C2 using information derived from the broader ABMS network. There is utility to alternate pathways of achieving mission goals. It affords a fallback that mitigates the vulnerabilities posed by an exceedingly high reliance on connectivity links. It also complicates an adversary's calculus because U.S. forces would be pursuing a C2ISR solution set with a wide breadth of technical approaches. The net effect is a resilient, robust system.

As for crew size, the previous JSTARS recapitalization effort, focused on business jet class aircraft, demonstrated that technological advancements were able to automate many functions previously executed by human operators. Such trendlines will continue, which would afford a streamlined approach to onboard air battle manager manning requirements. Certain functions could also be disaggregated to air battle managers elsewhere in the battlespace, with the Air Force exploring concepts that include dual-tasking aerial refueling aircraft as C2 nodes.[71] While a positive idea, it is important to recognize that an aircraft like the KC-46 will have primary mission duties—namely refueling. C2 will require airmen in the right time and place to net desired effects. This emphasizes the value yielded by a dedicated C2ISR platform. Supplementary additions provide value, but they are also not dealbreakers should their primary task functions degrade their C2 functionality.

The net effect of this proposed C2ISR construct would yield a layered vision whereby C2 in high threat environments sees a collaborative, integrated three-phase approach:

1. Penetrating, highly survivable sensor nodes, paired with space-based systems, linked to C2 operators providing real-time decision-making inputs.
2. High speed, high altitude manned C2ISR sensor platforms able to provide supplementary "look-in" and network-sourced decision-making insights, as well as extensive, survivable C2ISR coverage over moderate risk regions
3. Stand-off C2 and ISR systems able to gather and process data into decision-quality outputs.

The advantage of this construct is simple: to guide force employment decision-making in a timely, encompassing manner with a high level of prioritization for redundant capabilities, sufficient capacity, and mission-based affordability. Most importantly, it relies on a balanced approach to information, connectivity, and C2. Each of these facets are represented proportionately.

Conclusion

Upon reviewing the state of C2 in the years immediately following the Cold War, the 18th Secretary of Defense Les Aspin remarked, "We know how to orchestrate [technology] in a way that makes the sum bigger than all the parts."[72] That statement holds true today more than ever. Technology will prove essential in ensuring combat assets will be employed effectively and efficiently in alignment with the commander's intent. However, it is crucial to pursue a balanced approach when it comes to developing the next-generation construct.

Networks, AI, automation, and machine learning will prove essential in yielding an enhanced, robust system that speaks to the needs of tomorrow's operating environment. The Air Force is on track in this regard. However, these technologies do not obviate the importance of C2 tiered appropriately throughout the battlespace. Professionals will still need to be positioned appropriately throughout the C2 decision structure. Additionally, options must afford redundancies and flexibility that can enhance high-end operations and allow assets to be employed elsewhere in the threat spectrum when required.

This requires a new model for positioning air battle managers throughout the battlespace so that they will be poised to connect to and support defined forces in circumstances where adversaries will be seeking to defeat communications links. An overreliance on extended network connections only introduces new levels of vulnerability. Air battle managers staged throughout the operating space ensure a greater chance of connectivity. Innovative concepts like supersonic C2ISR aircraft should be a key part of the consideration, as should alternate aerial operating locations—like on aerial refueling and other mission type aircraft that will be occupying relevant positions in the battlespace for extended periods of time. Such concepts speak to the power of disaggregating C2 from ISR, while still holding options for integrated C2ISR should networked solutions find themselves immobilized due to enemy interference.

The investment for this sort of solution—one that will push significant advances in network technology, processing ability, automation, AI, machine learning, and new aircraft designs—will be considerable. However, given what is at stake, the question should be reversed: what is the cost of not pursuing this approach? The Air Force is simply too small, too old, and too fragile to meet its taskings through pure numbers superiority. Even if the requirement for 386 operational squadrons is realized, pressing mission demands will necessitate the effective and efficient employment of this force.

The Battle of Britain stands as a cautionary tale for today's leaders. On September 15, 1940, with Britain facing one of the largest German attacks of the entire conflict, Prime Minister Winston Churchill visited an air defense command and control center responsible for directing RAF fighters against the attacking German forces. Watching the waves of incoming German attackers on the center's plotting boards, Churchill asked "What other reserves have we?" Air Vice Marshal Keith Park replied, "There are none."[73] Decades later, the story is often romanticized as an example of stoic airmen defending their nation against the odds. In actuality, it portrays a country teetering on the brink of disaster. Britain won that fight in no small measure thanks to information, connectivity, and C2. The same will be true in future wars for which our nation's air force must be prepared. The U.S. Air Force's investment in the modern equivalents must stand as top priorities. ✪

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About the Author

Douglas A. Birkey is the executive director of the Mitchell Institute for Aerospace Studies. He is an expert on aerospace power technology, history, and defense resourcing. An experienced Capitol Hill staffer and government relations professional, Birkey has authored numerous documents that have informed defense legislation and has also written extensively on aerospace and defense issues. Prior to becoming Mitchell's executive director, Birkey was the director of government relations for the Air Force Association. Birkey holds an M.A. from Georgetown University.