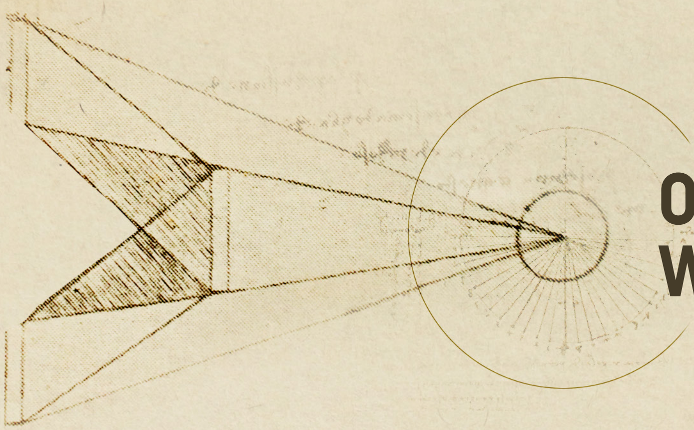

ON FUTURE WAR

OCTOBER 2024

Cockpit or Command Center?

C2 Options for Collaborative Combat Aircraft

Benjamin Jensen, Christopher "Wyatt" Koeltzow, Allen Agnes, and Eric Williams[1]

In the future...

- **Networks of manned and unmanned aircraft will command the skies.** These teams will be increasingly modular and optimized for counterair, interdiction, and close air support missions.

- **A mix of war games, Red Flag exercises, and dynamic home station simulations will test the ability of airmen—on the ground and in the skies—to execute mission command through networks of unmanned aircraft** and respond to rapid changes in the threat environment. Together, these experiments will help guide not just airpower, but the entire joint planning and targeting cycle, into an era of algorithmic warfare.

Introduction

There is a new theory of airpower on the horizon. Over the next five years, the U.S. Air Force (USAF) plans to invest **billions in research and development** for a force of over **1,000 collaborative combat aircraft** (CCA). The vision includes working with **allies and partners** to pair fourth- and fifth-generation aircraft with versatile unmanned systems, creating aerial networks that can rapidly adapt to changes in the battlespace. Multiple **reports** and **war games** portend a new future in which unmanned systems will replace an aging, expensive manned aircraft and create entirely new mission profiles optimized for peer conflict. The fate of these unmanned systems is critical, given both the Air Force's decision in July 2024 to **reevaluate its sixth-generation aircraft** and the emergence of new **Air Task Forces**.

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1 The authors would like to thank the following individuals for earlier review comments: David Blair (Colonel, USAF), Matthew Strohmeyer (Colonel, USAF), Alex Chesney (Major, USAF), and Josh Williams (Major, USAF).

Yet how will military organizations command and control distributed networks of CCAs in future air operations? Will such networks be proverbial “loyal wingmen,” subject only to the tactical commands of a pilot in a cockpit? Or will drones do the bidding of the command centers, like **Combined Air Operations Centers** (CAOCs)? **The command and control (C2) architecture surrounding CCAs will almost certainly prove to be as consequential as the systems themselves in forging the future of air power.** The U.S. military needs a clear concept of mission command for autonomous aircraft, executed across multidomain battle networks and tailored to different mission types.

There is a fundamental tradeoff between tactical responsiveness and operational effectiveness. Where missions require time-sensitive adjustments, CCA C2 should center on the mission leader and ensure pilots have the right mix of high-bandwidth, low-latency comms and human-factor-optimized software to help them respond to the chaos and complexity of aerial combat. Where missions require concentration and unity of effort—the alignment of mass and objective—CCA C2 should focus on operational planning and mission execution directed from command centers. The Air Force and other aviation arms across the services need to invest in flexible **battle networks** and in concepts and training regimes that help adapt the core processes of command and control to the realities of modern warfare. To achieve this, **the USAF should start conducting more robust studies and war games involving C2, alongside an accelerated series of experiments.** It is one thing to pick a new piece of equipment; it is another to forge new doctrines and processes around the equipment.

The Third Offset Takes Flight

The concept of pairing unmanned combat aircraft with traditional air formations dates back to the notions of “the Third Offset” and “**the loyal wingman**.” The **Third Offset**—a term coined by former deputy secretary of defense Robert Work in 2014—proposes the use of technological advantages to offset Russia’s and China’s abilities to amass combat power. Its theory of victory was to ensure that the United States retained a generational lead in weaponry. As part of this strategy, defense analysts envisioned a new, unmanned “**loyal wingman**” that could increase the performance of fourth- and fifth-generation combat aircraft.

Many of the initial loyal wingman tests involved turning fourth-generation fighter aircraft into remotely piloted vehicles. For example, during the 2017 **Have Raider II** experiments, Lockheed Martin Skunk Works paired an unmanned F-16 with a manned ground station to test autonomous flight during simulated air-ground strikes. In 2023, the USAF unveiled **Project Venom**, a series of experiments designed to load autonomous code into six F-16s and test the systems’ operation across a range of missions. These efforts built on **earlier experiments** that focused on perfecting the software necessary for autonomous flight. These experiments continue today through the Defense Advanced Research Projects Agency (DARPA)’s **Air Combat Evolution** program, which tests prototypes like the **X-62A**.

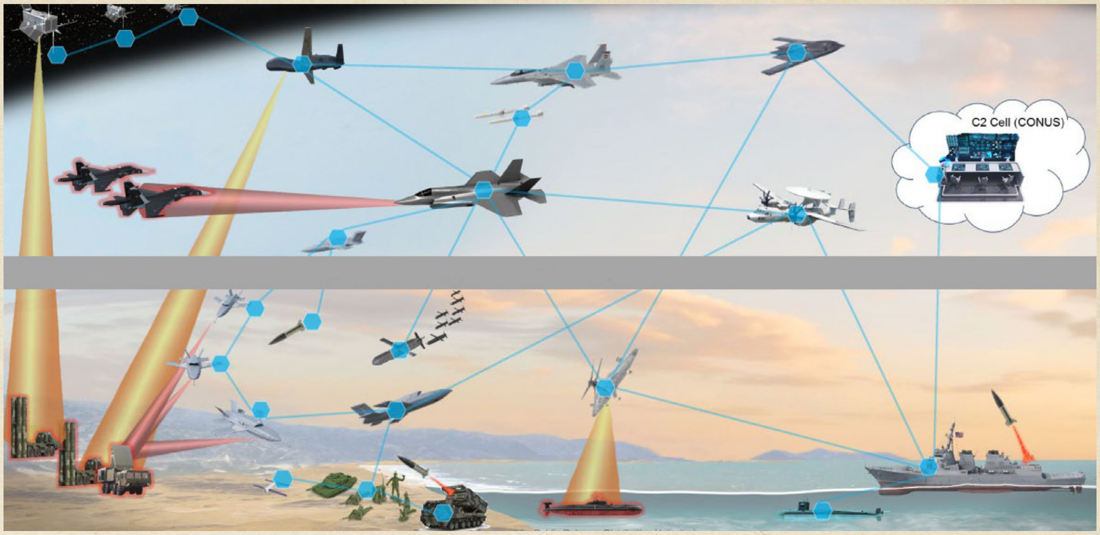
CCA concepts have since evolved beyond adapting fourth-generation platforms to building unmanned aircraft with treaty allies. Over the past year, five companies submitted CCA designs,

This installment of the *On Future War* series explores tradeoffs in command and control (C2) concepts for CCAs to help usher in a new era of air power through an analysis of future campaign scenarios.

two of which—General Atomics and Anduril—the **Air Force** is now considering. The General Atomics candidate is the **Gambit**, built to change configurations for different mission profiles to maximize **fungibility**. **Anduril** entered the CCA contest via its 2023 acquisition of Blue Force, whose group 5 vehicle, Fury, will be integrated with Anduril's family of autonomous vehicles.

Both firms share a vision of using software to optimize hardware performance and interoperability—an idea that grows out of earlier work by DARPA, including the **Adapting Cross-Domain Kill-Webs** (ACK) program and the larger concept of **mosaic warfare**. In line with this vision, CCAs will not only increase the survival of manned aircraft, but also enhance lethality by enabling software-defined kill webs.

Figure 1: Advanced Battle Management System



Source: "Emerald Flag exercise begins," Air Force Life Cycle Management Center, December 1, 2020, https://www.aflcmc.af.mil/News/Article-Display/Article/2432103/emerald-flag-exercise-begins/.

This vision also extends to allies and partners. Building on their own experiments with the Boeing Ghost Bat, the **Australians** are looking to establish trilateral cooperation with the United States and Japan on CCAs. **Japan** is increasing its investments in multiple unmanned programs, including the **Global Combat Air Platform**, which is under development with Italy and the United Kingdom. Not to be outdone, India is on schedule to start flight testing its CCA variant later in 2024. In December 2022, France, Spain, and Germany sealed a **3.2-billion-euro** agreement for **Europe's** Future Combat Air System (FCAS) program. In February 2024, the United Kingdom released its **Defence Drone Strategy**, highlighting the country's efforts with unmanned aircraft systems.

China and Russia have introduced similar concepts and prototypes. In 2022, the People's Liberation Army Air Force (PLAAF) unveiled its FH-97A "**Loyal Wingman**" drone, designed to operate alongside fifth-generation fighters like the J-20 and J-31, which are currently undergoing **extensive upgrades**. The PLAAF approach to CCAs seems to be to replicate existing low-cost U.S. prototypes like the **XQ-58A Valkyrie**, which is currently being developed by the Air Force Research Laboratory and the Marine Corps. The Russian defense establishment, led by the Advanced Research Foundation, has long pursued unmanned aerial systems with advanced features and integration capabilities. The development of the Altius and S-70 Okhotnik-B—the latter integrated with the **Su-57**, Russia's fifth-generation multirole aircraft—provide compelling evidence of Russian CCA endeavors.

Taken together, these initiatives point to a prevailing trend across multiple countries: the addition of unmanned aircraft as key nodes in multidomain networks designed to execute traditional airpower missions like counterair operations, interdiction, and close air support. Similar to earlier DARPA concepts, these nodes enable the delegation of key tasks and support missions across a software-defined kill web. This pairing of manned and unmanned systems puts a premium on command and control, prioritizing the execution of **mission command** through algorithms that guide autonomous systems.

Command and Control

As states race to integrate CCAs into their air forces, a question remains: *How will militaries command and control new formations?*

Command is a continuous function that consists of key subtasks: collecting and distinguishing relevant information, translating it into estimates to determine objectives and courses of action, converting these plans into orders, and monitoring progress through assessments. Command takes the form of a **system** that links together a focal point—the commander—with a staff that aligns its intent with the commander's key decisions. In **Marine Corps doctrine**, command encompasses decisionmaking as well as the directing of others; control concerns feedback loops and the management of a "continuous flow of information about [an] unfolding situation." As a result, the C2 architecture for CCAs must factor in who directs the platforms and how feedback loops are analyzed in a fluid environment with shifting objectives.

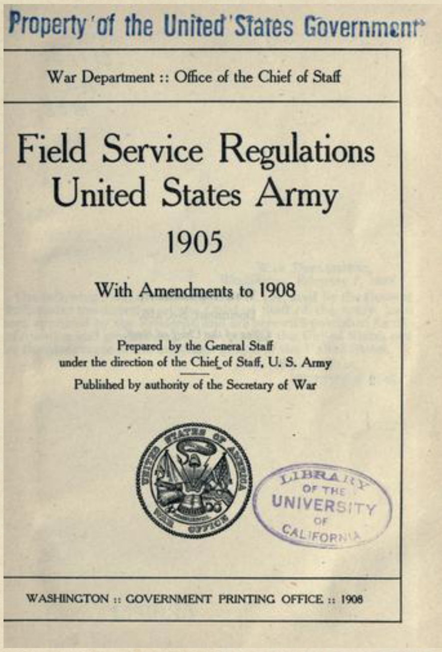
A recurring theme in the evolution of airpower has been the usage of C2 to concentrate and sequence tactical air effects in time and space while also allowing the airman in the cockpit flexibility in emerging situations. In the aftermath of Operation Desert Storm, a historical study by **James Winnefeld and Dana Johnson** defined C2 as "unity of effort." The study analyzed a joint air operation between the Army Air Corps, Marines, and Navy to thwart Japan's invasion of Midway. While strategically successful, the Battle of Midway revealed a lack of operational unity of effort between land-based and sea-based air campaigns. This absence of coordination persisted through the Korean War, where service rivalries hindered joint air operations.

The Battle of Midway had a single commander overseeing all air assets. In Korea, the Air Force, Marine Corps, and Navy were divided in their command structures. Despite efforts at coordination, joint operations continued to be plagued by interservice rivalries, conflicting doctrines, and poor communication. The Vietnam War further exposed these issues, demonstrating the need for significant changes to achieve true unity of effort.

The process of managing joint airpower has evolved since World War II, largely due to the **Joint Targeting Coordination Board's** efforts to deconflict service perspectives on mission priorities. In the 1970s, the military streamlined the chain of command by giving the Chairman of the Joint Chiefs of Staff (CJCS) greater authority and by emphasizing the role of combatant commanders (COCOM) in joint operations. This move toward greater coordination was further solidified by the Goldwater-Nichols Department of Defense Reorganization Act of 1986. The result was the introduction of a Joint Forces Air Component Commander (JFACC), as well as the development of the master attack plan (MAP) and air tasking order (ATO), which improved **centralized control and coordination** of air assets and was used to great effect in **Desert Storm**.

Yet operational unity of effort must also accommodate the fluidity of tactical combat, where the unforeseen can create new and unforgiving realities. When not accompanied by tactical flexibility, centralized C2 can create brittle systems.

This dilemma is addressed in the doctrines of multiple services, which emphasize the need to balance centralized control with decentralized execution. **Air Force doctrine, for example**, dictates the conduct of operations through centralized command, distributed control, and decentralized execution (CC-DC-DE). In this framework, mission flexibility and combat lethality are maximized through the generation of mission-appropriate sorties, allowing the commander to adapt to circumstances. In **Marine Corps antiair warfare**, this is referred to as the principle of centralized command and decentralized control.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War Department :: Office of the Chief of Staff

Field Service Regulations
United States Army
1905

With Amendments to 1908

Prepared by the General Staff
under the direction of the Chief of Staff, U. S. Army
Published by authority of the Secretary of War

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Both ideas center on the concept of mission command. **The core of mission command is a culture of trust and a blueprint for disciplined initiative at all echelons based on the commander's intent.** While the concept dates back to nineteenth-century operational art, mission command entered U.S. military writings **formally in 1905**. The concept evolved over the years, eventually giving rise to a core idea adapted for airpower in 1962: *centralized command and decentralized execution.*[2]

As an approach to command and control, mission command represents both a philosophical tenet and a set of planning and operation processes designed to foster a culture of initiative. For generations, Army and Marine Corps doctrines have grounded the concept in a belief that war is an **inherently chaotic** contest (Zweikampf) defined by **friction, uncertainty, and fluidity**. As a result, combatants must balance operational synchronization—the movement of large formations to fight decisive battles in time and space—with tactical adaptations that allow subordinates to anticipate and respond to changing circumstances. Applied to CCAs, this means that networks of autonomous aircraft will have to balance operational effectiveness and tactical efficiency. Mission command will need to be integrated into algorithms to make it possible for pilots to delegate aspects of air-to-air combat to drones and react to feedback from the edge of the battlefield—whether they're in a ground command center or in an **airborne warning and control system** (AWACS) aircraft.

In the chaos of battle, it is essential to decentralize decision authority to the lowest practical level because over centralization slows action and leads to inertia.

FM 100-5 (1986)

While airmen are highly capable of decentralized execution, the modern joint air tasking cycle also codifies principles of centralized command and operational synchronization. This six-stage cycle matches air capabilities and effects against larger, operational objectives—as defined by the Joint Force Commander—and results in an ATO that shape the **joint air operations**.

2 Of note, 1962 was also the first year the Army formally mentioned mission-type orders as vehicles for executing mission command.

The first stage of the joint air tasking cycle is "Objectives, Effects and Guidance," which provides guidance on objectives and desired effects. The final product for this stage is the air apportionment recommendation, which is provided by the JFACC in consultation with other component commanders.

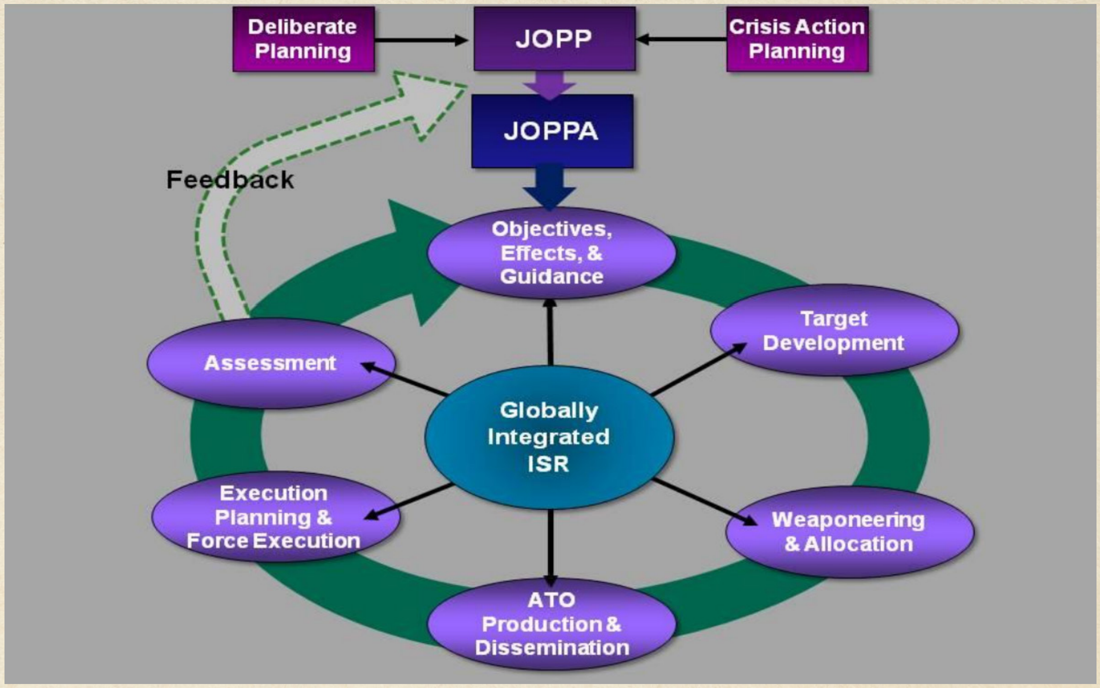
The next stage, "Target Development," matches targets to air taskings and aimpoints, which are fed to the Targeting Effects Team (TET). The TET then reviews, nominates, and prioritizes targets, ensuring that each attack meets JFC guidance. The product of this effort, when approved by the JFC, is the joint integrated prioritized targeting list.

Next, in the "Weaponeering and Allocation" stage, the Joint Air Operations Center quantifies the expected results of employing all available means in every domain against prioritized targets. The final targets are then delivered to the master air attack plan team. Following the JFC's air apportionment decision, a final number of sorties by weapon system is developed for each objective and task.

The fourth stage is "ATO Production and Dissemination," in which the ATO production team constructs, publishes, and disseminates the daily ATO and Special Instructions to appropriate forces. The ATO includes information such as the order of battle, target worksheets, and component requirements.

In the fifth stage, "Execution Planning and Force Execution," the JFACC directs air capabilities and forces in joint air operations. During this stage, the JFACC has the ability to redirect air assets and coordinate with component commanders.

Figure 2: Contingency and Crisis Execution: The Tasking Cycle



Note: JOPP is Joint Operational Planning Process and JOPPA is Joint Operational Planning Process for Air.
Source: "Contingency and Crisis Execution: Tasking Cycle," Air Force Doctrine Publication (AFDP) 3-0: Operations and Planning, Curtis E. LeMay Center for Doctrine Development and Education, November 4, 2016, https://www.doctrine.af.mil/Portals/61/documents/AFDP_3-0/3-0-D29-I-OPS-The-Tasking-Cycle.pdf.

During the final stage, “Assessment,” a continuous process measures the overall effectiveness of joint force capabilities at both the tactical and operational levels. Assessment is not the end of the cycle, but rather a continuous activity that provides input at all the stages of the cycle.

Even this carefully choreographed process, however, cannot match the infinite range of possibilities that emerge in war. Air operations require decentralized execution as pilots respond to the friction, uncertainty, and fluidity of war. The loadout of CCAs will be determined by the air tasking cycle—with airmen loading different payloads and sensor arrays—but their employment may have to adjust to sudden changes at both operational and tactical levels.

At the operational level, situations may emerge that demand a sudden realignment of missions, leading the CAOG commander to override the ATO to respond to a new threat. For example, imagine a squadron of F-35s operating with CCAs to conduct a fight sweep to seek out and destroy enemy aircraft. The command post receives indications that a squadron of enemy fifth-generation fighters are moving to attack a high-value air asset (HVAA) and are likely to overwhelm friendly fighters. The HVAA is hundreds of miles from the intended fighter sweep. To the extent that CCAs are capable of remote-split operations separate from the flight leader, they are **operationally effective** and the CCAs can be redirected to support HVAA protection, leaving the F-35s to continue the sweep—albeit at greater risk than originally planned.

At the tactical level, CCAs must support delegations by pilots already overwhelmed by the massive amount of information generated by modern aircraft. This delegation should be an extension of commanders’ intents and allow the CCAs to perform with initiative within the limits of the mission. CCAs need to be able to respond to changing tactical situations noticed either by the pilot or by sensors feeding algorithms supporting autonomous systems. This kind of feedback loop is the essence of decentralized execution; if CCAs lack it, they are likely to render missions brittle, causing overwhelmed pilots to have to manage more information—in their cockpit and on devices controlling CCAs—than the human mind can process, especially amid physical stress and fear. According to the **Mike Tyson** retelling of **Moltke** and **Eisenhower** quotes, “everyone has a plan until they get punched in the face.” Seeing, dodging, or taking the blow to set up a counterstrike are the essence of being **tactically responsive.**

Moreover, CCAs will need to be capable of executing mission command at both operational and tactical levels, with optimal C2s determined by mission type. In some missions, the value of operational effectiveness outweighs the utility of tactical responsiveness. The inverse is also true; other missions require tactical responsiveness to a degree that outweighs the benefits of perfect operational effectiveness. Much of the modern air tasking cycle is built around a C2 architecture that links CCAs to the command center, rather than to the pilot in the cockpit. From the development of objectives, effects, and guidance to target development to master attack planning, the majority of flight planning takes place in command centers, even when orchestrated through nodes like AWACS. Since a command center has a wider perspective than any individual mission leader, nesting C2 for CCAs there ensures that assessments are indeed a continuous activity. Economies of scale afforded by centralized control should not be immediately discounted due to the lure of the fighter pilot.

Yet in complex missions that require tactical-level delegation, CCAs have the capability to reduce the cognitive burden on pilots, thus extending their reach. This increase in efficiency should translate into superior mission performance. An F-35 accompanied by two CCAs loaded with air-to-air missiles and decoys will likely produce more air-to-air kills than a single aircraft, even if the two have comparable weapons loadouts. Likewise, a group of 10 F-35s and F-15Xs flying alongside 100 CCAs would be even more effective. To the extent that algorithms are an extension of mission command, the pilot is free to see and respond to change based on mission command.

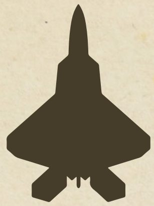
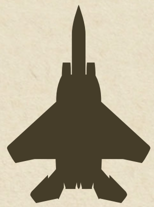
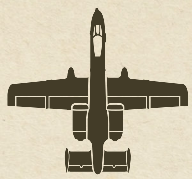
The future of air power, as waged through networks of manned and unmanned systems, will depend on tailoring CCA algorithms to the logic of each mission. Unlocking the full potential of CCAs will require wargames, experiments, and studies that explore mission command in various scenarios and new C2 models by mission type. These experiments will need to incorporate new concepts for generating Air Task Forces based on new **combat wings** optimized for great power competition. Furthermore, the experiments will need to stress-test new task forces employing **Agile Combat Employment** (ACE), an operational scheme of maneuver, and multidomain **pulse operations**. In other words, distributed networks of aircraft will have to come together from distributed airfields and synchronize airpower with cyber warfare—and other technical means—to create windows of opportunity. To be operational, these efforts must take into account multiple pulse operations, as well as the ability to generate combat power in and through the air over the course of a campaign. That task will require deeper digital integration and data synthesis—using artificial intelligence and machine learning—from multiple warfighting functions, as well as the imagining of entirely new ATOs that are more joint and dynamic. **Software will be as important as hardware in this vision of future airpower.**

The following exploration analyzes hypothetical air campaigns through the lens of the fundamental tradeoff between operational effectiveness and tactical responsiveness. From reflecting on the **combined bomber offenses** in World War II and **air war over Vietnam** to **John Warden and the Gulf War** and the **Balkans**, the air campaign is the preferred **unit of analysis for operational study**. While air campaigns tend to involve a mix of missions, the scenarios below will visualize and describe three campaigns that are each oriented around a mission area: counterair operations, interdiction—including both **counterland** and **countersea** operations—and **close air support**.

This analytical framing is frequently used in Air Force studies. The **Battle of Britain**, for instance, has been used to study counterair operations; a wide range of cases—from **World War II** to the wars in **Korea** and Vietnam—have been used to study the **development of close air support** and **interdiction**.

Below, a fictional planning scenario is used to analyze three future campaigns: counterair operations, interdiction in littoral environments, and close air support. In each, the adversary is intentionally kept abstract in order to focus the analysis on the C2 character of the mission sets, which are evaluated in terms of operational effectiveness and tactical responsiveness. The adversary is held constant across all three scenarios and assumed to be a peer competitor capable of contesting U.S. power across multiple domains, including air. Other major assumptions include:

1. The United States is fighting as part of a larger coalition of partners and allies (the norm throughout its history).
2. The conflict involves nuclear powers but has not crossed the threshold where either side uses nuclear weapons in pursuit of strategic or operational objectives.
3. While there have been large exchanges in space and cyberspace, all sides retain the ability to support air, ground, and maritime operations with space and cyber capabilities.

Mission	
	**Counterair Operations.** Offensive and defensive operations to attain and maintain control of the air, as well as protect friendly forces, by neutralizing or destroying threats from all domains that directly or indirectly challenge control of the air. These missions include offensive counter air (OCA), encompassing attack operations, suppression of enemy air defenses (SEAD), fighter escort, and fighter sweep, as well as defensive counterair (DCA), or active and passive air defense. Aircraft play a larger role in active air and missile defense.
	**Interdiction.** Air operations conducted to divert, disrupt, delay, or destroy the enemy's military potential before it can be brought to bear effectively against friendly forces. These missions include aerial interdiction (AI), on-call AI (GAI), airborne alert AI (XAI/XINT), and strike coordination and reconnaissance (SCAR). In countersea operations, additional missions include war-at-sea strike (WAS), airborne maritime mining (AMM), and SCAR for the maritime domain.
	**Close Air Support.** Action by aircraft against hostile targets near friendly forces, requiring detailed integration with the movement and fire of those forces. Includes "pull CAS" (GCAS) for on-call missions placed on ground alert status and "push CAS" (XCAS) for on-call missions on airborne alert status in the vicinity of ground forces expected to encounter enemy resistance.

Definitions adapted from *Air Force Doctrine Publication 3-01: Counterair Operations,* U.S. Air Force, June 15, 2023, https://www.doctrine.af.mil/Portals/61/documents/AFDP_3-01/3-01-AFDP-COUNTERAIR.pdf; *Air Force Doctrine Publication 3-03: Counterland Operations*, U.S. Air Force, October 21, 2020, https://www.doctrine.af.mil/Portals/61/documents/AFDP_3-03/3-03-AFDP-COUNTERLAND.pdf; and *Air Force Doctrine Publication 3-04: Countersea Operations*, U.S. Air Force, September 20, 2023; https://www.doctrine.af.mil/Portals/61/documents/AFDP_3-04/3-04-AFDP-Countersea-Ops.pdf.

Campaign Scenario: 20XX

It is 20XX, and the United States finds itself engaged in a regional war as part of a coalition seeking to stop an authoritarian state from illegally annexing the territory of one of its neighbors. After a series of space, cyber, air, and maritime operations over the initial thirty days, there is now a forward line of troops (FLOT), with the United States providing air support to partner ground forces as additional units mobilize. This leads to a series of battles in air, at sea, and on land as each side seeks to gain a position of advantage along the FLOT.

In planning the next phase and delineating how best to sequence major operations in pursuit of objectives, the Coalition Joint Task Force (CJTF) is exploring options for three different air campaigns: (1) counterair, (2) interdiction, and (3) close air support.

The counterair campaign would prioritize gaining air superiority to open up a ground or maritime counteroffensive. At present, there is air parity, and each side has yet to roll back the other side's air defense network or sufficiently attrite the other side's air force to establish air superiority. The resulting air parity makes it difficult to achieve more than a tactical breakthrough on the ground or to forward-deploy naval surface combatants integrated into CJTF operations. This results in a static FLOT and long lines of communication that burn readiness and risk creating a protracted conflict. The counterair campaign would dedicate all available air assets to establishing air control, if not supremacy, before transitioning to major operations in other domains.

The **interdiction campaign** would prioritize striking targets across the depth of the littorals to shock the enemy system and create conditions for a localized counterattack. The mission would establish temporary air control to enable air interdiction against both enemy lines of communication and logistical nodes just beyond the FLOT, which are critical to projecting power through littorals. By strangling the enemy and channeling its movement into a series of kill boxes in the joint fires area, the campaign would set conditions for a simultaneous air and ground counteroffensive. This emphasis on simultaneity differentiates the interdiction campaign from the phasing and sequencing of the counterair campaign.

The **close air support campaign** would prioritize generating effects on the FLOT to enable a breakthrough. Unlike the interdiction campaign, the priority of air control is along the FLOT and enabling **terminal attack control** (TAC) based on guidance given by the ground commander to joint terminal attack controllers (JTAC). This campaign would combine type 1, 2, and 3 controls to enable close coordination between coalition ground forces and aircraft. This coordination, and the ability to mass air effects on key ground objectives, sets conditions for an operational envelopment along the FLOT. Like the interdiction campaign, the emphasis is on simultaneity. Unlike the interdiction concept, the CAS campaign would focus on principles of objective and mass, using tightly coupled air and ground effects—including attack helicopters and loitering munitions in the **air-ground littoral**—to enable a decisive ground maneuver.

Tradeoffs in the Counterair Campaign

In the fictional scenario above, the counterair campaign would mix offensive and defensive counterair to establish air superiority. There are historical precedents in multiple World War II cases, in which novel methods were used to bait German fighters as part of the Royal Air Force (RAF) **circus offensive** that followed the Battle of Britain.

In a campaign setting, which involves longer time periods and multiple major operations, planners must focus on attrition rates and how best to pull an adversary into air operations that produce diminishing marginal returns. Every sortie generates losses that exceed the value of the mission. Losses inhibit the enemy's ability to generate air power, changing how the adversary fights (i.e., assigning aircraft to missions) while reducing the time and space required to achieve air superiority.

This notional counterair campaign would almost certainly rely on a mix of **SEAD** and fighter sweeps to establish air superiority. Modern radars, especially when connected to space effects, enable situational awareness and tracking. Establishing air superiority first requires blinding the enemy and destroying its ability to track and target friendly aircraft. Second, if enemy planes cannot be destroyed on the ground—the best place to kill an aircraft—they must be engaged in a series of operations designed to change the balance of air power.

Supermarine Spitfire Mk Vb of No. 92 Squadron, May 19, 1941.

Photo: G. Woodbine/Second World War Official Collection/Imperial War Museums

These missions, even with intelligence over-match, would likely require CCAs that are more tactically responsive. Air-to-air combat and the adjustment to unforeseen aspects of an adversary's air defenses—as seen in the evolution of **SEAD missions** since Vietnam—require the ability to recognize and respond to changes in the tactical environment. Feedback loops create a fluid environment prone to sudden changes.

Mission command for CCAs in these situations takes the form of pilots directly adjusting mission parameters in response to a changing environment. This would likely require building in preconstructed mission sets that the pilot can rapidly assign as the threat environment changes. For example, consider a fighter sweep in which two F-35s are each paired with four CCAs, mixing electronic countermeasures and air-to-air weapons. The flight leader receives confirmation that there are more enemy aircraft than originally anticipated and relative to the payload. She could dynamically retask the CCAs to jam and harass the enemy combat air patrol while the manned aircraft pull back to regroup and assess the situation with an AWACS and/or the command center (e.g., CAOG). Decentralized execution takes the form of an ability to assign missions to networked CCAs in order to free up time and space for pilots to adjust to new information.

Alternatively, DCA would focus more on a mix of active and passive defenses. In modern war, these cut across multiple domains and include everything from space-based sensors to AEGIS destroyers and patriot missile sites. Aircraft play a role that includes shooting down cruise and loitering munitions—as seen both in the April 2024 **defense of Israel** from an Iranian strike and in the skies of **Ukraine**—but that role tends to be supporting as opposed to supported. This dynamic puts a premium on operational effectiveness and on empowering an air defense commander to integrate air and missile defense to include a larger number of land platforms (e.g., surface-to-air missiles, radars, directed energy, high-powered microwave) and sea platforms (e.g., naval cruisers, destroyers, and frigates) alongside airborne networks of manned and unmanned aircraft. Mission command applies here, but managing air and missile threats across large areas requires more centralized control measures, whether in an AWAC or a ground-based command center.

Tradeoffs in the Interdiction Campaign

In the fictional planning scenario above, the interdiction campaign would combine both counterland and countersea air operations focused on denying the enemy power projection in the seams of the air, sea, and ground. In **U.S. joint doctrine**, this littoral environment includes "those land areas (and their adjacent sea and associated air space) that are predominantly susceptible to engagement and influence from the sea and may reach far inland." Modern battle networks and long-range precision fires extend the segments of air, ground, and sea that constitute the site of modern **littoral warfare**.

The most likely targets of the interdiction campaign would be logistics nodes and lines of communication. The theory of victory is that reducing the enemy's supplies reduces its combat power, creating a more favorable correlation of forces for offensive action and/or limiting the ability of the enemy to project power. This logic is evident across multiple, historical interdiction campaigns, which carry a **different theory of victory** than strategic attack and which are built around decisive blows against enemy C2.

During the Italian campaign, allied planners designed **Operation Strangle** as an independent air interdiction campaign targeting German supply lines, intended to render the planned ground offensive (Operation Diadem) unnecessary. The effort had mixed results and led to an enduring debate about whether to target enemy supplies or mobility. This debate shaped air interdiction campaigns in Korea. For example, the **Saturate interdiction campaign** targeted North Korean rail lines to reduce supply, focusing on a narrow corridor on a continuous basis.

The effects are not limited to counterland operations. Maritime interdiction played a key role in World War II. The **RAF Coastal Command**, for instance, was pivotal to the Battle of the Atlantic, in sub-hunting missions in the Bay of Biscay, and in attacks on marine lines of communication connecting Germany to key industrial materials in Scandinavia. Of note, many of these efforts benefitted from work by technical experts who integrated new technologies, including air-to-surface radar and applied **operations research**—the use of formal mathematical models and statistics to analyze patterns and trends in armed combat. The Luftwaffe replicated this maritime interdiction capability through its **Fliegerführer Atlantik**.

In Vietnam, Operation Rolling Thunder (1965–1968) was largely an **air interdiction campaign**, with over 90 percent of the targets consisting of transportation nodes. In addition to destroying combat potential by targeting supplies and lines of communication, interdiction can **channel the enemy's movements**, attriting its forces. Of Desert Storm's 40,000 strike sorties, roughly 38,000 were air interdiction. Some of these missions included the attack on the infamous "**Highway of Death**," where coalition aircraft destroyed Iraqi forces retreating from Kuwait into Iraq.

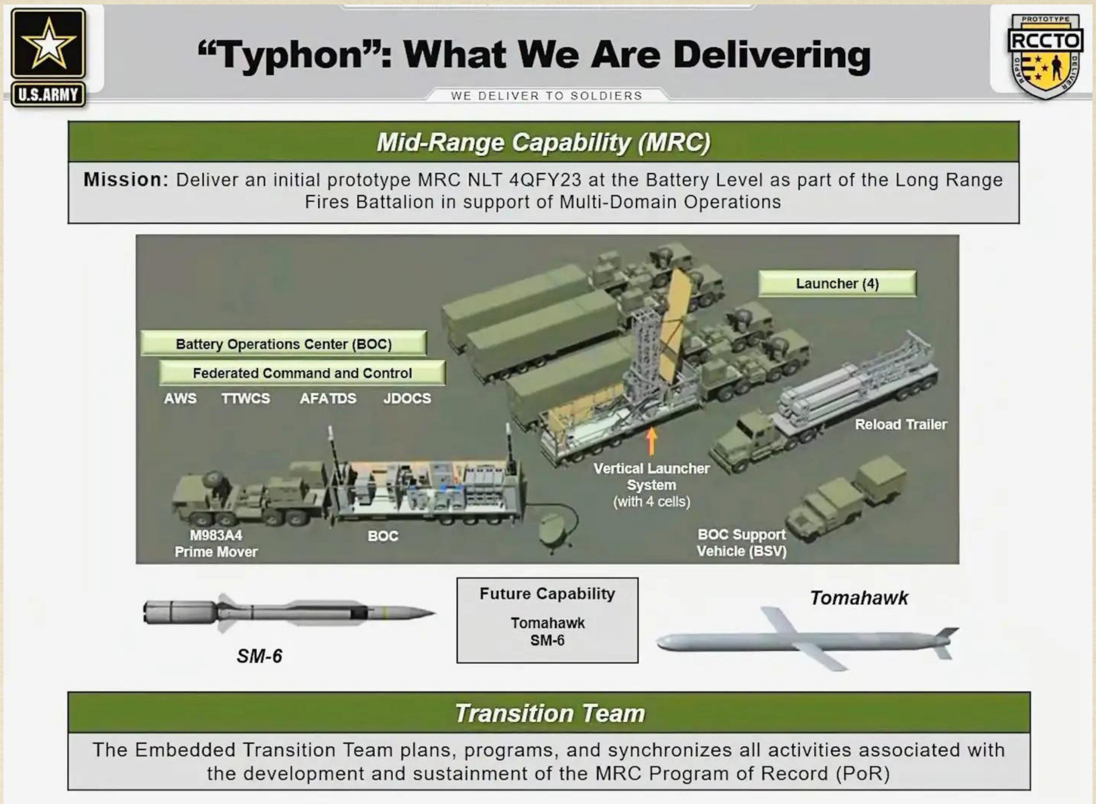
Interdiction requires operational-level coordination and careful target selection. These missions naturally lend themselves to a C2 architecture that executes mission command through a command center. CCAs could become part of a larger joint fires scheme for interdicting lines of communication; they could carry a mix of electronic attack payloads and air-ground (or air-sea) munitions, which work alongside long-range strike assets currently fielded by the Marine Littoral Regiment and the Army's Multi-Domain Task Force.

In addition, CCAs could act as escorts for long-range strike munitions targeting naval logistics vessels and amphibious shipping, protecting the missiles from being shot down by enemy air patrols. Consider an **MDTF Typhon battery** and an AEGIS Destroyer firing a salvo of Tomahawk

The "Highway of Death," the result of U.S. forces bombing retreating Iraqi forces, Kuwait, 1991.

Photo: Photo 12/Universal Images Group via Getty Images missiles at a key target. Through joint fires coordination, the CAOG could task on-call CCAs to carry a mix of payloads to support the mission, freeing up human pilots for other missions. While the same salvo could be supported by a manned-unmanned team, the theater-level fires synchronization makes it more aligned with C2 oriented toward operational effectiveness.

Figure 3: Mid-Range Capability Supporting Multidomain Operations



Source: Typhon briefing slide, Rapid Capabilities and Critical Technologies Office presentation, U.S. Army.

One exception is strike coordination and reconnaissance (SCAR). These missions are the interdiction equivalent of a movement to contact. They are **flown** to detect and target enemy units in a defined geographic area where "potential targets are known or suspected to exist, or where mobile enemy ground units have relocated because of ground fighting." This uncertainty and fluidity put a premium on tactical responsiveness. A network of manned and unmanned aircraft can—consistent with **Joint Interdiction** doctrine—cycle "multiple attacking flights through the target area and provid[e] prioritized targeting guidance and enemy air defense updates to maximize the effect of each sortie." In this case, mission command extends through the cockpit to the CCA for decentralized execution as the flight leader responds to unforeseen changes. For example, an F-15X or F-35 flying alongside 10 CCAs would be able to respond not just to its own sensors but to a larger constellation of joint and interagency capabilities in order to identify and disrupt enemy targets.

As in counterair operations, CCAs performing interdiction roles would need preplanned mission profiles to support autonomous execution. Humans will still be in the loop, encoding rules of engagement and strike deconfliction when necessary. At the same time, **the entire joint fires doctrine and framework will need to test how new campaign concepts relate to existing**

doctrine and to the targeting cycle. Again, it is one thing to enable CCAs to fly. It is another to integrate them into planning and staff processes that took decades, if not centuries, to emerge in the military profession. There will need to be new, flatter joint architectures optimized for multidomain effects and dynamic joint targeting cycles.

Tradeoffs in the Close Air Support Campaign

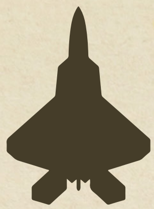
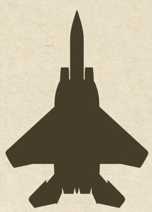
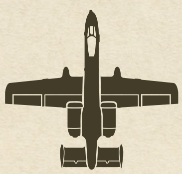
In the fictional planning scenario above, focusing air power at the FLOT would require deep air-ground integration. In the chaos of combat, changing planned missions to take advantage of emerging ground conditions also requires a great degree of flexibility. This defining requirement puts the C2 architecture squarely in the tactical responsiveness camp, albeit with a twist. The JTAC on the ground becomes a kind of cockpit.

Procedures for CAS have evolved since World War II. Following the fall of France, the **Wann/Woodall Report** recommended creating a distinct communication network to connect ground radios to aircraft under special circumstances. This concept laid the foundation for the emergence of CAS C2 and the Tactical Air Force task organization used in **experiments in North Africa** (e.g., the Desert Air Force). **Failures** during the 1942 Dieppe Raid (Operation Jubilee) further showed the need for new C2 constructs that integrated tactical air and army formations. **Close air support** concepts continued to evolve between 1943 and 1945 in campaigns in Italy and Northwest Europe. By the **Normandy Campaign**, air-ground integration procedures had matured to differentiate between **indirect and direct support**, setting the foundation for modern CAS. These procedures played a critical role in the **Battle of the Falaise Pocket**, to which RAF hurricanes made essential contributions.

This iterated approach to developing deeper air-ground integration continued across multiple conflicts in the late twentieth century. Each major war, according to historian I.B. Holley Jr., saw the military profession relearn the importance of air-ground teamwork. Whether in Korea or Vietnam—or in Israel's experience across multiple conflicts—practitioners had to adapt air-ground communications, liaison relationships, and procedures to new technologies and air defense schemes. In Holley Jr.'s view, analyzing this history and learning the lessons of past air campaigns is a requirement for updating future CAS doctrine.

CCAs offer a new opportunity to refine **close air support** concepts and doctrine in a manner that reflects deeper service integration than in previous wars. In other words, CCA design features and USAF doctrine should integrate with Army, Navy, and Marine Corps concepts, leading to potential change in joint doctrine. If CCAs are built to only perform counterair missions, they miss an opportunity to realize their full potential.

This potential could see the emergence of new procedures in which JTACs on the ground take control of CCAs to conduct CAS and to deconflict airspace, thus maximizing joint effects against key targets. In the aforementioned fictional scenario, consider an enemy force attempting to break out of a beach landing site and seize an airport. This breakout would likely involve a concentration of artillery and air defense moved forward to support ground formations, with **air-launched effects** and **loitering munitions** serving as an advanced guard. Containing the breakthrough would require forward JTACs **coordinating CAS** and other **joint fire support** to destroy, disrupt, suppress, fix, harass, neutralize, or delay advancing enemy columns in support of the ground commander's defensive plan. The fog, friction, and chaos of the ground battle undermine operational effectiveness and put a premium on tactical responsiveness. In a major ground campaign, operational art for joint fires is about logistics and building a C5ISR-T network able to support dynamic targeting and operational reach.

Mission		Operational Effectiveness	Tactical Responsiveness
	**Counterair Operations.** OCA operations like fighter sweeps and SEAD require a C2 architecture oriented around the cockpit. Alternatively, integrating networks of manned and unmanned CCAs into air defense requires a C2 architecture oriented around command nodes and operational effectiveness.	✓ DCA	✓ OCA ✓ SEAD
	**Interdiction.** Missions that focus on preplanned and on-call counterland operations (e.g., AI, GAI, XAI/XINT) alongside countersea air operations like WAS and AMM require a C2 architecture oriented toward command nodes and operational effectiveness. Alternatively, more dynamic missions like SCAR require a C2 architecture built around cockpits and tactical responsiveness.	✓ AI ✓ GAI ✓ XAI/XINT ✓ WAS ✓ AMM	✓ SCAR
	**Close Air Support.** Missions that focus on both push and pull CAS require a high degree of air-ground integration. The cockpit becomes the JTAC on the ground, responsible for coordinating the release of the munitions. In this case, the emphasis is on tactical responsiveness, but there are possibilities for a CCA whose control is passed from the CAOG to a JTAC.		✓ GCAS ✓ XCAS

Definitions adapted from *Air Force Doctrine Publication 3-01: Counterair Operations,* U.S. Air Force, June 15, 2023, https://www.doctrine.af.mil/Portals/61/documents/AFDP_3-01/3-01-AFDP-COUNTERAIR.pdf; *Air Force Doctrine Publication 3-03: Counterland Operations*, U.S. Air Force, October 21, 2020, https://www.doctrine.af.mil/Portals/61/documents/AFDP_3-03/3-03-AFDP-COUNTERLAND.pdf; and *Air Force Doctrine Publication 3-04: Countersea Operations*, U.S. Air Force, September 20, 2023; https://www.doctrine.af.mil/Portals/61/documents/AFDP_3-04/3-04-AFDP-Countersea-Ops.pdf.

Conclusion: Exercises, Wargames, and Doctrine

Looking across the three fictional planning scenarios provides an insight into the refinement of C2 requirements for CCAs.

As the table above indicates, the future of air power and mission command will require a mix of systems and procedures that enable both tactical responsiveness and operational effectiveness. It is not enough to just build unmanned platforms that respond to flight leaders via simple interfaces that clutter an already-crowded cockpit. Even the simplest command interface will require detailed human factors engineering studies on cognitive overload to ensure CCAs don't overwhelm human pilots.

This will require testing different cockpit C2 interfaces in dynamic settings like Red Flag Exercises, along with the introduction of enhanced simulation capabilities in the USAF's new command wings. Replicating the stress of counterair, SCAR and CAS missions will be the only way to gauge the optimal cockpit C2 structure for connecting the best of the human pilot with the functionality of the CCA.

There is also a need to develop new experiments that test the current planning and air tasking cycle, ideally through wargames that inform new concept development and doctrine for tasking CCAs through command posts. These wargames should parallel ongoing experiments like the Global Information Dominance Experiments (GIDE) and Project Convergence. The more services and coalition partners involved in stress-testing the current approach to planning and coordinating the delivery of joint effects, the better the insights will be. These experiments offer a valuable forum to test emerging ideas, from the Joint Warfighting Concept and related priorities to service-level force design and development initiatives. In other words, proper C2 architecture for CCAs has the potential to unlock innovation across the U.S. military. And that innovation will require a mix of exercises, wargames, and even study groups that will act as incubators for developing new concepts and capabilities. In all likelihood, an entirely new planning and tasking process for joint effects could emerge from this experimentation campaign, closing the deterrent gap.

These experiments will need to stress-test the ability of new software architectures to connect networks and evaluate data streams from disparate sources. Consistent with prior recommendations, these efforts should also include options for democratizing and digitizing C2 to allow for the rapid upload and transfer of data packets from a wide mix of civilian and military sensor networks. Again, there is as much art as there is science in the development of these mosaic-like systems, and in the balancing of tactical responsiveness and operational effectiveness.

The modern American way of war is defined as much by mission command as by massing effects. Because modern combat takes place along complex battle networks, centralized command and decentralized execution must work in and through algorithms. **The challenge of twenty-first century operational art, therefore, will be deciding how best to pair human judgment with the precision and speed of machines.** As a result, determining the optimal C2 architecture for executing mission command through CCA networks should be a national security priority. ■

Benjamin Jensen *is a senior fellow in the Futures Lab in the International Security Program at the Center for Strategic and International Studies (CSIS) in Washington, D.C., as well as the Petersen Chair of Emerging Technology and a professor of strategic studies at the Marine Corps University School of Advanced Warfighting.* ***Colonels Christopher "Wyatt" Koeltzow*** *(USAF),* ***Allen Agnes*** *(USAF), and* ***Eric Williams*** *(USMC) were 2024 military fellows at CSIS. The views expressed here are the authors' own and do not reflect any official government position.*

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Leonardo da Vinci Sketches: wowinside/AdobeStock