DEFENSE, EMERGING TECHNOLOGY, AND STRATEGY PROGRAM

Autonomous Drones Will Not Replace Fighter Pilots, They Will Be Their Wingmen

Collaborative Combat Aircraft are the Next Generation of Unmanned Warfighting Aircraft

Brian Moscioni

HARVARD Kennedy School
BELFER CENTER
50 YEARS OF RESEARCH, POLICY, AND LEADERSHIP

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Executive Summary

This paper presents the argument that while unmanned aerial vehicles (UAVs) have advanced significantly throughout the previous two decades, they will not be replacing human fighter pilots any time soon. Instead, UAVs are being designed to function as their wingmen. The U.S. Air Force (USAF) Next Generation Air Dominance (NGAD) program introduces "Collaborative Combat Aircraft" (CCAs). These semi-autonomous drones are designed to fly alongside human-piloted aircraft, like the newly announced F-47, acting as force multipliers in military aviation.

The advancements in artificial intelligence (AI), machine learning (ML), and large language models (LLMs) are the driving forces behind CCAs functioning as highly capable wingmen, including increased situational awareness, enemy engagement, and onboard decision-making. Over the years, the evolution of UAVs, from the MQ-9 Reaper and RQ-4 Global Hawk, to cutting-edge prototypes like Anduril's CCA, known as *Fury,* demonstrates how unmanned systems have grown in capability but have not removed the need to keep a human-in-the-loop (HITL).[1]

DARPA's Air Combat Evolution (ACE) program and the AlphaDogfight Trials demonstrated the viability of AI becoming highly integrated with military aviation platforms. The culmination of the AlphaDogfight Trials resulted in an AI agent decisively defeating a highly skilled human fighter pilot in a simulated dogfight. However, limitations remain, including human trust in autonomous systems, technical challenges like hallucinations and latency in AI systems, and the ethics of migrating to a more unmanned-dominant military aviation operational environment.

The VISTA F-16 test aircraft represented critical proof-of-concept integration of AI into present-day crewed aircraft. This platform has conducted multiple autonomous test flights, further validating the concept of manned-unmanned teaming (MUM-T).

1 Ge Wang, "Humans in the Loop: The Design of Interactive AI Systems."

This paper also presents three policy recommendations:

1. Increase Department of Defense (DoD) research, development, and funding towards the creation of the NGAD and CCAs.
2. Develop CCAs in cooperation with allied militaries to increase interoperability between platforms, mission sets, and areas of operation (AORs).
3. Continue to encourage and foster an environment of manned aircraft through the end of the century.

CCAs are poised to become the next generation of future military aviation warfare through the advancements made in artificial intelligence, combined with traditional, advanced human-pilot aircraft. UAVs, still, do not represent an era for the replacement of fighter pilots, but rather an augmentation which will enhance capabilities and ensure the United States maintains a competitive military edge amid rising geopolitical tensions. Continued research and development, cooperation, and funding will be paramount for the successful implementation of these new aircraft.

Introduction

Fifteen years ago, American students aspiring to be the next "Top Gun", were told that if they struck the correct balance between hard work, the right timing and sheer luck to make it into the cockpit of a pointy-nosed, gray military jet, that they would represent the last generation of fighter pilots. Unmanned aerial drones, like the MQ-9 Reaper and RQ-4 Global Hawk, had started proving their value in the early to mid-2000s in Iraq and Afghanistan.[2,3] Riding off this success, top military officials, private defense contractors, and unmanned aircraft enthusiasts were fueling the hype of this nascent drone technology, making bold predictions that the days of having a man or woman in the cockpit of military combat aircraft were sunsetting. In 2009, the U.S. Air Force (USAF) provided public information that it was "training more drone operators than fighter and bomber pilots", and had started to communicate "the end of the era of the fighter pilot."[4] Likewise, a few years later, in April of 2015, Secretary of the Navy Ray Mabus publicly proclaimed that "the F-35 should be, and almost certainly will be, the last manned fighter aircraft the Department of the Navy will ever buy or fly."[5]

But in March of 2025, the United States Air Force announced its Next Generation Air Dominance (NGAD) platform, a manned aircraft, designated the F-47.[6] It takes an immense investment to start a fighter aircraft program; the development of the F-35 cost nearly $2 trillion, making it the most expensive military project in history. Therefore, the decision to keep a human being in the cockpit for decades to come is not a small one.[7] As a new generation of American students now aspire to fly the U.S. military's first 6th generation fighter jet, what happened to the strong proclamations made by military and defense experts earlier this century? For now, it appears the military has developed a solution for the use of unmanned aerial drones: Collaborative Combat Aircraft (CCA).

2 Secretary of the Air Force Public Affairs, "MQ-9 Reaper Enhances Air Force Capabilities in Iraq."

3 Secretary of the Air Force Public Affairs, "RQ-4 Global Hawk."

4 Edward Helmore, "US Air Force Prepares Drones to End Era of Fighter Pilots."

5 Sam Lagrone, "Mabus: F-35 Will Be 'Last Manned Strike Fighter' the Navy, Marines 'Will Ever Buy or Fly.'"

6 Secretary of the Air Force Public Affairs, "Statement by Chief of Staff of the Air Force Gen. David Allvin on the USAF NGAD Contract Award."

7 Alistair MacDonald, "The World's Top Jet Fighter Is About to Get More Expensive."

The Concept Behind Collaborative Combat Aircraft

The United States Air Force is leading the charge in building a fleet of Next Generation Air Dominance (NGAD) aircraft. The USAF refers to NGAD as a "'family of systems' enabling air superiority".[8] Concurrently, other service branches, including the United States Navy (USN), are peering into the 6th generation aircraft efforts by the Air Force, and, perhaps, by the end of the decade, all U.S. military branches with aviation components will have started experimenting with CCAs.[9] CCAs are unmanned aircraft that are intended to serve as force multipliers, flying alongside advanced manned aircraft, like the F-47. CCAs will operate as semi-autonomous wingmen, flying in tandem with piloted aircraft, readily able to deliver nearly the same mission capabilities as the crewed aircraft.[10] This manned-unmanned teaming (MUM-T) will allow the pilot(s) to operate at a higher level of situational awareness (SA) and with less task saturation. DARPA states that "in a future air domain contested by adversaries, a single human pilot can increase lethality by effectively orchestrating multiple autonomous unmanned platforms from within a manned aircraft."[11]

At their current stage of development, CCAs are at a technology readiness level (TRL) of 6 and nearing level 7. TRL level 6 is defined as: "System/process prototype demonstration in an operational environment."[12] Part of what makes their development so difficult is determining the level of automation these autonomous aerial vehicles (AAVs) are intended to have. As CCAs are still an unproven concept, the current target ability of automation is between a level 3 and a level 4, or a conditional automation level to a high automation level.[13] When referring to CCAs, DARPA says that these AAVs will have "a hierarchical framework for autonomy in which higher-level cognitive functions (e.g., developing an overall engagement strategy, selecting and prioritizing targets, determining best weapon or effect, etc.) may be performed by a human, while lower-level functions (i.e., details of aircraft maneuver and engagement tactics) is left to the autonomous system."[14] Because

8 Jennifer DiMascio, "U.S. Air Force Next-Generation Air Dominance (NGAD) Fighter."

9 Matthew Cox, "Navy Eyes 'Interchangeable' CCAs with Air Force, Lessons from MQ-25."

10 Mikayla Easley, "Air Force Wraps up Critical Design Review for Increment 1 of CCA Drones."

11 Ryan Hefron, "ACE: Air Combat Evolution."

12 "Technology Readiness Levels Definitions and Descriptions."

13 Miriam McNabb, "DRONEII: Tech Talk – Unraveling 5 Levels of Drone Autonomy."

14 Ryan Hefron, "ACE: Air Combat Evolution."

there is such a diverse array of mission sets for fighter aircraft, these autonomous parameters will look different based on which type of mission they are flying or which type of manned aircraft they are supporting within the MUM-T.

Last year, the Air Force awarded Anduril and General Atomics funding for the "detailed design, manufacture, and testing of production representative test articles under the Collaborative Combat Aircraft program".[15] Anduril's CCA model, named "Fury" (YFQ-44A), and General Atomic's CCA model, currently designated as YFQ-42A, will take flight in mid-2025.[16] The collaborative combat aircraft of these two companies will "harness cutting-edge disruptive technologies such as autonomy, machine learning and AI to maximise the safety and performance of current and future fighter fleets for agile combat employment."[17] CCAs will complement the fight by providing early warning sensors, radar, electronic warfare (EW) capabilities, supplemental weapons, and more to fulfill the duties of a multi-role fighter platform.[18]

Recognizing a rapidly evolving warfighting landscape, Anduril's "Fury" aircraft utilizes modular subsystems and is designed to be adaptable for new capabilities to counter future threat actors.[19] A functionality called "lattice for mission autonomy" is integrated into the design and allows "Fury" to be highly customizable to integrate "different platforms and payloads, made by different vendors, into different mission solutions for different mission requirements."[20] Lattice for mission autonomy was developed to not only allow a single operator to control a multitude of drones, but the software is also "hardware agnostic", which allows for seamless integration and simultaneous operation of many dissimilar AAVs.[21]

General Atomics, a veteran developer of unmanned aerial vehicles (UAVs) used by the military, is already testing autonomous software on its existing airframes across a number of mission sets.[22] It plans to leverage its more than three decades in the UAV business to build affordable aircraft that are highly customizable through the use of a common aircraft fuselage design.

15 Secretary of the Air Force Public Affairs, "Air Force Exercises Two Collaborative Combat Aircraft Option Awards."

16 Secretary of the Air Force Public Affairs, "Air Force Designates Two Mission Design Series for Collaborative Combat Aircraft."

17 "Collaborative Combat Aircraft (CCA), USA."

18 "Next Generation Air Dominance Programme."

19 Anduril, "Autonomous Air Vehicle."

20 Anduril, "Lattice for Mission Autonomy."

21 Joe Saballa, "Anduril Unveils Software for Controlling 'Hundreds' of Drones."

22 "GA-ASI Selected to Build CCA for AFLCMC."

Evolution of Artificial Intelligence (AI) in Drones

"At its core, AI is about recreating aspects of human intelligence in machines – perception, reasoning, learning, and even creativity."

— Demis Hassabis, CEO of DeepMind[23]

First taking flight in 1998, the Northrop RQ-4 Global Hawk is loosely considered to be the UAV that first utilized artificial intelligence, with features like automatic takeoff and landing, waypoint navigation, and other simple features.[24] While this is not typically what comes to mind when referencing artificial intelligence by today's standards, these UAVs could perform these functions by following preprogrammed decision logic.[25] Similarly, the early General Atomics MQ-9 Reaper utilized rudimentary artificial intelligence to enhance operability in its environment. In 2009, the director of the 21st Century Defense Initiative at The Brookings Institution, Peter W. Singer, emphasized that the Reaper "is highly lethal and is so packed with AI that it can make decisions on its own."[26]

Also in 2009, an Air Force report on unmanned aerial systems (UAS), titled "United States Air Force Unmanned Aircraft Systems Flight Plan 2009-2047", presented a lofty vision and laid the initial groundwork for what UAVs would someday evolve into. This report theorized the use of "loyal wingman technology" nearly two decades before it would become reality through conceptualizing tactical evolutions like swarm (many UAVs operating in the same environment) or using automation and artificial intelligence to identify and act on detected images and sensory information.[27]

By 2010, the Navy unveiled its unmanned combat air system carrier (UCAS) program, developing two prototypes designated the X-47B.[28] These UCAS models

23 Demis Hassabis, Demis Hassabis: DeepMind.

24 Airman 1st Class Patrick S. Ciccarone, "RQ-4 Global Hawk Makes First Flight out of Misawa."

25 Michael B. Donley and General Norton A. Schwartz, "United States Air Force Unmanned Aircraft Systems Flight Plan 2009-2047."

26 "War Machines of Afghanistan."

27 Michael B. Donley and General Norton A. Schwartz, "United States Air Force Unmanned Aircraft Systems Flight Plan 2009-2047."

28 "X-47B Unmanned Combat Air System (UCAS)."

were the first unmanned, fixed-wing aircraft that were designed to land aboard a naval aircraft carrier. Not only was it the first unmanned aircraft to do so, but it was designed to perform these operations autonomously. The X-47B had the capabilities to take off from the carrier, join up next to another aircraft, perform aerial refueling, and then return to the deck of the aircraft carrier.[29] This advancement of autonomy in UAVs, where the aircraft could navigate complex tasks on its own with only "the occasional click of a mouse from an operator to send it instructions" was a monumental proving ground for follow-on development.[30]

Moving forward to the UAV software being developed today, advanced tools like machine learning (ML) and large language models (LLMs) are being used to develop the artificial intelligence that allows these unmanned vehicles to perform their own reasoning and operations. "LLMs have recently gained significant attention as they enable systems to learn from application behavior and optimize existing systems."[31] LLMs are also advancing further to include vision reasoning capabilities, referred to as large (vision) language models (L(V)LMs). These new models "integrate visual understanding with language processing," which can assist UAVs in perception, the ability to plan and make decisions, and to generate data.[32] Similarly, vision-language-action models (VLAMs) allow machines to "feel" their presence in three-dimensional reality.[33] These advancements, amongst others, have led to the ability to engineer Collaborative Combat Aircraft. However, in order for these aircraft to effectively complement fighter aircraft, they also have to learn to fight and maneuver like a fighter jet.

DARPA's Air Combat Evolution and the AlphaDogfight Trials

Generally speaking, there are two types of aerial engagements for a fighter pilot: beyond-visual-range (BVR) and within-visual-range (WVR).[34] Within-visual-range engagements, popularly known as dogfighting, are an extremely challenging

29 "X-47B Unmanned Combat Air System (UCAS)."

30 Sharon Weinberger, "X-47B Stealth Drone Targets New Frontiers."

31 Javaid, Saeed, and He, "Large Language Models for UAVs: Current State and Pathways to the Future."

32 Li et al., "A Survey of State of the Art Large Vision Language Models: Alignment, Benchmark, Evaluations and Challenges."

33 "Robots Are Suddenly Getting Cleverer. What's Changed?"

34 CNATRA P-825, "Basic Fighter Maneuvering (BFM) and All Weather Intercept (AWI)."

evolution where the pilot must know the limits of their aircraft, the limits of the enemy aircraft, and the proper techniques, coordination, and timing to employ the weapons they carry. It is a complex series of variables and timing that comes down to three main types of "spatial relationships: range, angles, and closure."[35] It is a very taxing and demanding exercise for human pilots to perform. Theoretically, an aircraft using artificial intelligence would be able to employ a suite of sensors and computer logic and reasoning to perform these tasks more effectively and more efficiently, but it remains a challenge to create such software.

DARPA created a program to address this exact challenge. Called the Air Combat Evolution (ACE), the "program seeks to increase trust in combat autonomy by using human-machine collaborative dogfighting as its challenge problem" and "also serves as an entry point to complex human-machine collaboration."[36] Building human trust is an essential component of utilizing this system to its full capabilities. The pilot needs to trust that the CCA will be able to employ proper techniques of air-combat maneuvering (ACM), maintain physical separation to not collide with friendly aircraft, and have confidence that the CCA will target the correct enemy aircraft. ACE was created with the overarching goal to transition from "simple physics-based automated systems currently in use, to complex systems capable of effective autonomy within highly dynamic and uncertain environments at mission speeds."[37]

Creating a simulation environment to test the AI software that employed these tactical capabilities, DARPA contracted Johns Hopkins University Applied Physics Laboratory (APL) to allow eight contracted companies to compete and create the best AI model (agent). This competition became known as the AlphaDogfight Trials, or ADT. In what the APL personnel at Johns Hopkins named the 'Colosseum', developers were able to employ their AI models (agents) against each other in a 1-versus-1 simulation environment. As the trials played out, "these agents became progressively more complex, with the most highly advanced agents developed using deep reinforcement learning (RL) techniques that trained via self-play without human input."[38] These simulations were conducted in "faster-than-real-time" to quickly learn from each adversary and build upon its previously learned tactics with machine learning. To become progressively more

35 CNATRA P-825.

36 Ryan Hefron, "ACE: Air Combat Evolution."

37 Ryan Hefron.

38 Chirstopher R. DeMay et al., "AlphaDogfight Trials: Bringing Autonomy to Air Combat."

capable, the AI models flew against four different types of opponents (agents): rudimentary, basic, scripted, and RL (reinforcement learning). RL was designed to simulate an expert pilot. Johns Hopkins describes their RL agent as follows.

"The general paradigm for RL requires that an agent take one of a number of possible actions in an environment. The environment then provides feedback about the current state of the agent, along with a reward (either positive or negative). The agent can then learn the reward structure of the environment through repeated interactions, and it works to generate a strategy (policy) that maximizes the cumulative reward at the end of a sequence of interactions with the environment (game)."[39]

The final stage of the AlphaDogfight Trials was intended to put an advanced human pilot at the controls of a simulator and fly against the superior AI model. Heron Systems, the winning company, flew their AI model for a total of five iterations in a WVR aerial engagement against an F-16 weapons school instructor (equivalent to a Top Gun graduate in the U.S. Navy). The pilot, callsign "Banger", lost all five matchups against the Heron AI model.[40] ADT proved to be an incredible success and important advancement for the development of CCAs.

Of note, two variables were controlled and not acknowledged with enough emphasis in this experiment. The AI models were flying like-versus-like model aircraft, meaning F-16 vs. F-16, and were not flying against dissimilar aircraft. Aircraft type and model create an extraordinary difference when flying against each other in a WVR engagement. The second control was that the human pilot in the experiment was flying on a virtual reality (VR) headset. This means he was not subject to the g-forces and adrenaline that inevitably come with flying the actual aircraft. G-forces, beyond a certain threshold, limit a pilot's ability to masterfully fly an aircraft, a limitation that is not found in the AI models.

39 Chirstopher R. DeMay et al.

40 "AlphaDogfight Trials Foreshadow Future of Human-Machine Symbiosis."

Project Skyborg

Skyborg was a brief intermediate testing stage between developing artificial intelligence agents and then integrating the artificial intelligence agents into crewed aircraft. Started in 2019 and concluded in late 2021, Skyborg was designed to be tested on UAVs. A successful demonstration with two MQ-20 drones proved that both aircraft could operate autonomously and communicate with each other, "flying collaborative unmanned aircraft teaming experiments" with crewed F-22 fighter jets.[41] During this testing period, the "brain" of Skyborg, called the "autonomous core system", proved that it could be flown in several different types of UAVs. The Secretary of the Air Force at the time, Frank Kendall, said that Skyborg served "as the foundation, as a stepping-off point" so that the collaborative combat aircraft program was not "starting from zero."[42]

VISTA - From Simulator to Fighter Jet

Edwards Air Force Base is home to the Air Force's developmental test squadrons and many unique aircraft that cannot be found on any other military base in the world.[43] One of these aircraft, the Variable In-Flight Simulation Test Aircraft (VISTA), designated as the X-62A, is a highly modified version of the F-16 and became the first manned aircraft to be flown by artificial intelligence.[44] While this exact F-16 model was first flown in 1992, it was not fitted with the VISTA Simulation System (VSS) by Calspan until 2022.[45] The updated aircraft was also outfitted with a feature called the System for Autonomous Control of Simulation (SACS) to provide an array of autonomous testing capabilities and a system called Model Following Algorithm (MFA) developed by Lockheed Martin.[46] These upgrade efforts were performed in partnership with DARPA's ACE program. One of VISTA's most prominent features is a concept called "open systems

41 "Skyborg."

42 Greg Hadley, "'Wildly Successful' Skyborg Will Become Program of Record but Won't Stop Developing S&T."

43 Secretary of the Air Force Public Affairs, "Edward's History."

44 "VISTA X-62 Advancing Autonomy And Changing The Face Of Air Power."

45 Secretary of the Air Force Public Affairs, "NF-16D VISTA Becomes X-62A."

46 Ricardo Meier, "Unique F-16 Fighter, Vista X-62A Is Piloted by Artificial Intelligence in 17-Hour Flight."

architecture", which allows the jet to be installed with software that replicates the flight characteristics of other aircraft.[47] According to the US Air Force Test Pilot School (USAFTPS) director of research, Dr. M. Christopher Cotting, "VISTA will […] parallelize the development and test of cutting-edge artificial intelligence techniques with new uncrewed designs."[48] Being able to quickly substitute different AI models into this modified F-16 allows for rapid testing and post-flight analysis. In late 2022, the USAF started actual test flights with this aircraft, and in 2023, VISTA started flying against human-piloted aircraft.[49]

During the first several flight tests, the VISTA flew into the "merge" (the stage where two jets enter into a dogfight) at airspeeds above 1,200 miles per hour and aggressively performed offensive and defensive maneuvers. Two pilots remained inside the VISTA cockpit to monitor its performance while engaged against another manned F-16, and they never had to disengage the AI agent or take the controls throughout the evolution.[50] On May 2nd, 2024, Secretary Kendall went flying in the VISTA himself, sitting in the front seat. During this flight, ShieldAI, a prominent UAV company, provided the reinforcement-based learning AI that was present in the VISTA.[51]

As of December 2024, the Air Force has flown more than 20 flights while testing at least 12 different artificial intelligence agents on the VISTA.[52] ACE has gained a lot of insights from these tests. Not only are the ground and flight crews able to quickly update the software between sorties, but sometimes they are able to do so mid-flight.[53]

Difficulties During Development

Despite great leaps forward, many obstacles still need to be addressed and debugged. Brigadier General Doug Wickert of the 412th Test Wing at Edwards Air Force Base has discussed "gaps" in testing, mentioning that artificial

47 "VISTA X-62 Advancing Autonomy And Changing The Face Of Air Power."

48 "VISTA X-62 Advancing Autonomy And Changing The Face Of Air Power."

49 Stephen Losey, "US Air Force Stages Dogfights with AI-Flown Fighter Jet."

50 Stephen Losey.

51 "Inside the AI-Enabled Pilot That Flew Air Force Secretary Kendall Through a Dogfight."

52 Mikayla Easley, "Air Force Wraps up Critical Design Review for Increment 1 of CCA Drones."

53 Stephen Losey, "US Air Force Stages Dogfights with AI-Flown Fighter Jet."

intelligence can do "unexpected things" during flights.[54] Some of the issues include phenomena such as hallucinations, latency, interference, or safety and ethical concerns.[55,56] Computer engineers regularly work to eliminate these faults within the AI agents.

A Glimpse at Next Steps

At present, the Air Force is looking to purchase at least 1,000 CCAs to accompany 300 new NGAD fighter jets and at least 200 F-35 fighter jets capable of operations with CCAs.[57] Funding is one of the focal points of making this goal a reality. Under the Defense Appropriations Act for fiscal year 2025, the Senate Appropriations Committee recommended transferring more than $551 million to CCA development efforts. Likewise, "the committee further expressed concerns that the Air Force has not provided enough money in its Future Years Defense program for fighter aircraft."[58] Citing concerns around the Air Force's ability to sustain air dominance in the coming decades, CCAs are well justified to continue to advanced stages of development and deployment. Collaborative combat aircraft may be used to assist bomber aircraft as well. With the announcement of the B-21 Raider bomber in December of 2024, Northrop Grumman revealed that this aircraft also has an open systems architecture and can be flown either manned or unmanned. Being a "digital bomber", the aircraft will utilize artificial intelligence, cloud-based technology, and a suite of other advanced technologies.[59]

During his appointment, USAF Secretary Frank Kendall incorporated China's aerospace advancements into the future calculus of the U.S. Air Force planning. On September 16, 2024, at an Air, Space and Cyber conference, he was quoted as saying that "China is a threat today", drawing attention to action needed now, and emphasizing that this is no longer a future problem.[60] China's People's Liberation Army Air Force (PLAAF) has been test flying two new 6th generation aircraft: the

54 Mikayla Easley, "Air Force Leveraging AI Flight Experiments to Inform Future Testing Efforts."

55 Li et al., "A Survey of State of the Art Large Vision Language Models: Alignment, Benchmark, Evaluations and Challenges."

56 Javaid, Saeed, and He, "Large Language Models for UAVs: Current State and Pathways to the Future."

57 "Collaborative Combat Aircraft (CCA), USA."

58 Jennifer DiMascio, "U.S. Air Force Next-Generation Air Dominance (NGAD) Fighter."

59 "Here Are 10 Key Facts about the Northrop Grumman's B-21 Raider:"

60 "China Is 'a Threat Today,' US Air Force Official Says."

J-50 stealth fighter and the J-36 bomber.[61] Of note, based on the photographs that have been taken, both of these 6th generation aircraft appear to have manned cockpits. Likewise, a research paper by six Chinese researchers titled "Manned and Unmanned Aerial Vehicles Cooperative Combat Framework Based on Large Language Models" was released in September of 2024, which addresses some of the emerging science behind manned-unmanned teaming (MUM-T) and highlights similar ambitions by Chinese military forces.[62] Indications from several fronts are validating the need for continued advancement of collaborative combat aircraft.

Policy Recommendations

Recommendation 1: Increase Department of Defense (DoD) research, development, and funding towards the creation of the NGAD and CCAs.

Description: The United States has not invested in an advanced air-superiority fighter jet aircraft since the F-22 Raptor in 2005.[63] In that time, Russia and China have developed several 5th generation air-superiority aircraft and are beginning to sell those platforms on the international market.[64,65] To not "lose the edge", the United States needs to act quickly in finding a replacement for the F-22 Raptor. While the F-47 (NGAD) has been announced as America's first 6th generation aircraft, prioritization needs to be emphasized on its development and mobilize the Department of Defense to do everything in its power to avoid cost overruns and lengthy delays. Likewise, as a component of the NGAD family, CCAs must also continue development across a diverse array of operational applications. Defense funding should be prioritized to ensure the NGAD project is well supported up to and through initial operational deployment.

Reasoning: NGAD and CCAs are an essential component of America's projection of hard power. Today, considering the relevance of hypothetical tactical

61 Sakshi Tiwari, "U.S.-China 6th-Gen Aircraft Battle Heats Up As Beijing Increases J-36, J-50 Testing Amid US Push For F-47."

62 Hanyue Shi et al., "Manned and Unmanned Aerial Vehicles Cooperative Combat Framework Based on Large Language Models."

63 Secretary of the Air Force Public Affairs, "F-22 Raptor."

64 Shivam Patel and Abhijith Ganapavaram, "Russia Offers India Its Most Advanced Su-57 Stealth Fighter Jet."

65 Richard Thomas, "China Declassifies World-First Fifth-Generation Stealth Fighter Variant."

operations in the Far East, the F-22 Raptor is limited in payload and range, and would not perform strongly on high-endurance missions in the Indo-Pacific arena.

Recommendation 2: Develop CCAs in cooperation with allied militaries to increase interoperability between platforms, mission sets, and areas of operation (AORs).

Description: The United States military needs to work closely with its European allies in the development of their new Future Combat Air System (FCAS).[66] As CCAs are poised to enter service in a few years, the United States will benefit from the interoperability of a combination of allied air forces, as well as having the ability to commercialize our NGAD-capable weapon systems to EU forces. The U.S. military already regularly engages in several multinational exercises with its allies. Having the ability of American-made CCAs to link with NGAD-type aircraft of other allied nations would contribute to increased force mass. While the United States remains a global leader in technology and AI development, partnerships with other countries will result in increased benefits from supplemental research that is funded under allied military budgets.

Reasoning: The United States needs to maintain full operational capacity anywhere around the world, including through partnered nations. Failure to do so may create technological gaps and divides when operating in cooperation with foreign forces.

Recommendation 3: Continue to encourage and foster an environment of manned aircraft through the end of the century.

Description: For decades, it has been speculated that the end of manned military aviation, particularly tactical aviation, was a dying practice. It has become apparent, for reasons ranging from tactical to ethical to cultural, that a man or woman is still required in the cockpit. As the United States watches China develop several models of next-generation aircraft with human beings in the cockpit,

66 "Future Combat Air System (FCAS)."

it would appear that the need for manned aviation is still commonly desired amongst top military forces throughout the world. CCAs will be a monumental experiment, of course, with a highly anticipated degree of success. Resulting from lessons learned in this next generation of aviation innovation, the U.S. military will be better poised to make informed decisions on crewed versus uncrewed aircraft in the coming decades.

Reasoning: It is too soon to rule out manned aviation. While simultaneous research paths can be pursued, so long as they do not detract resources from each other, the focus should be directed towards crewed aircraft for the foreseeable future.

Conclusion

Collaborative Combat Aircraft represent a new generation of military aviation assets that embody the most advanced technological hardware and software developments of the present day. The adaptability of the open systems architecture in CCAs being designed today gives promise that these aircraft will remain relevant for years to come, even as AI models and software continue to develop at a rapid speed.

The policy recommendations herein are not mutually exclusive and should be exercised simultaneously. As the Chinese Communist Party (CCP) continues to build a "world class military" by 2049 and is incorporating policies of military-civil fusion (MCF), the United States needs to continue to advance and project its military hard power by developing state-of-the-art, next-generation military hardware.[67] CCAs are the future of military power projection from the skies, and America must work hard to maintain its advantage.

67 US Naval Institute Staff, "Pentagon Annual Report on Chinese Military and Security Developments."

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