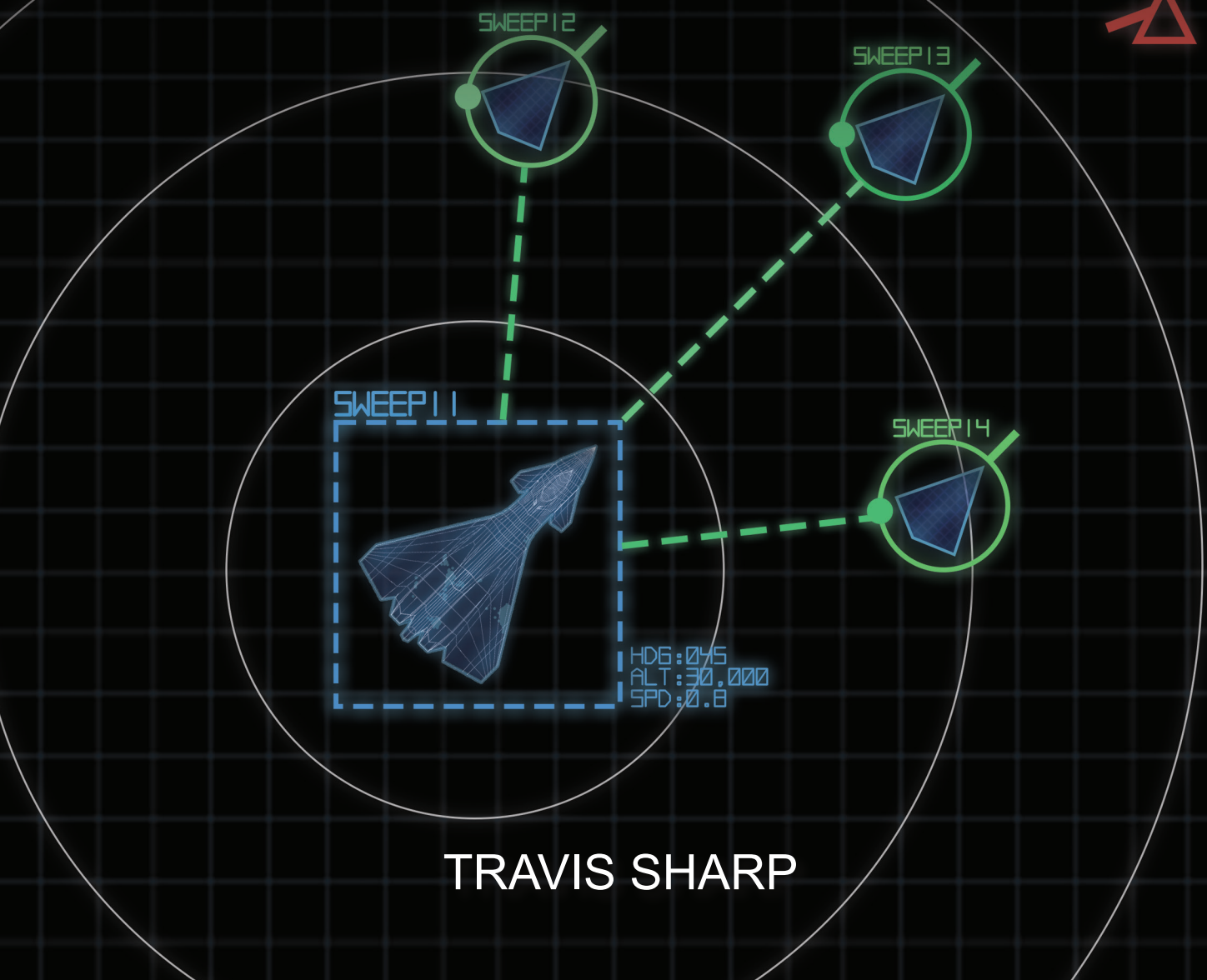
CSBA

Center for Strategic and Budgetary Assessments

READY PLAYER NONE?

AN END-TO-END ASSESSMENT OF THE AIR FORCE COLLABORATIVE COMBAT AIRCRAFT PROGRAM



TRAVIS SHARP

READY PLAYER NONE?

AN END-TO-END ASSESSMENT OF THE AIR FORCE COLLABORATIVE COMBAT AIRCRAFT PROGRAM

TRAVIS SHARP

CSBA
Center for Strategic and Budgetary Assessments

2025

ABOUT THE CENTER FOR STRATEGIC AND BUDGETARY ASSESSMENTS (CSBA)

The Center for Strategic and Budgetary Assessments is an independent, nonpartisan policy research institute established to promote innovative thinking and debate about national security strategy and investment options. CSBA's analysis focuses on key questions related to existing and emerging threats to U.S. national security, and its goal is to enable policymakers to make informed decisions on matters of strategy, security policy, and resource allocation.

ABOUT THE AUTHOR

Travis Sharp is a Senior Fellow at the Center for Strategic and Budgetary Assessments. He directs the defense budget studies program and works to inform policymakers, senior leaders, and the public about issues related to resourcing national security. He also serves as a lieutenant commander in the U.S. Navy Reserve and is a lecturer at The John Hopkins University's Paul H. Nitze School of Advanced International Studies. In 2023–2024, he served as a staff member on the National Defense Strategy Commission, a congressionally mandated bipartisan review group. He has held positions with academic and policy organizations including George Washington University's Institute for Security and Conflict Studies, the Office of the Secretary of Defense, and the Center for a New American Security. His research has appeared in *The Journal of Strategic Studies*, *Policy Sciences*, *Defense and Peace Economics*, *Journal of Defense Modeling and Simulation*, *International Affairs*, and other outlets.

ACKNOWLEDGMENTS

The author offers his sincerest thanks to Joe Ross for his many contributions to this report. He also thanks Casey Nicastro for early help with Chapter 3's budgetary analysis. For feedback on the report, he thanks Thomas G. Mahnken, Evan Montgomery, Greg Malandrino, Tyler Hacker, Chris Bowie, and the dozens of outside experts who shared insights but asked to remain confidential. The analysis and findings presented here are solely the responsibility of the author. CSBA receives funding from a broad and diverse group of contributors, including private foundations, government agencies, and corporations. A complete list of these organizations can be found on our website at www.csbaonline.org/about/contributors.

Cover graphic: Cover design by CSBA staff.

Contents

FIGURES

TABLES

Executive Summary

In 2023, the Air Force unveiled plans to acquire a fleet of autonomous unmanned collaborative combat aircraft (CCA) that would fly under the custody of manned aircraft pilots as loyal wingmen.[1] The Air Force proposed purchasing around 1,000 CCAs at a fraction of the F-35 fighter's current price but cautioned its inventory and cost targets likely would shift over time.[2] According to the Air Force, the CCA fleet's moderate cost and sizable inventory, a combination dubbed "affordable mass," will increase U.S. military effectiveness in a war with China by improving manned aircraft performance.[3] When teamed with CCAs, manned aircraft will suffer fewer losses and achieve more kills against Chinese air threats, according to service officials.[4]

The Air Force has cited forward sensing, air-to-air attack, and electronic warfare as the CCA's envisioned missions.[5] It views the CCA as part of a future ecosystem of autonomous unmanned collaborative platforms that will perform mobility, training, and other missions.[6] CCA development falls under the Next Generation Air Dominance (NGAD) program, which also includes the Air Force's sixth-generation manned fighter. The CCA's placement

1 The report does not analyze the Navy's collaborative combat aircraft (CCA) program because fewer public details exist about that initiative.

2 Stephen Losey, "U.S. Air Force Eyes Fleet of 1,000 Drone Wingmen as Planning Accelerates," *Defense News*, March 8, 2023, https://www.defensenews.com/air/2023/03/08/us-air-force-eyes-fleet-of-1000-drone-wingmen-as-planning-accelerates/.

3 Joseph Trevithick, "'Affordable Mass' Concept Driving Air Force's New Advanced Drone Initiative," *The War Zone*, March 10, 2023, https://www.thedrive.com/the-war-zone/affordable-mass-concept-driving-air-forces-new-advanced-drone-initiative.

4 Air & Space Forces Association Warfare Symposium, "Advancements in Collaborative Combat Aircraft CONOPs," March 8, 2023, 2, https://www.afa.org/app/uploads/2023/12/Advancements-in-Collaborative-Combat-Aircraft-CONOPs-Transcript.pdf.

5 Losey, "U.S. Air Force Eyes Fleet."

6 Caitlin Lee and Mark A. Gunzinger, *The Next Frontier: UAVs for Great Power Conflict, Part 1—Penetrating Strike* (Arlington, VA: Mitchell Institute, December 2022), 9, https://mitchellaerospacepower.org/the-next-frontier-uavs-for-great-power-conflict-part-1-penetrating-strike/.

within NGAD reflects the Air Force viewing it as a complement to manned aircraft, particularly fighters.

The CCA exemplifies a new phase in the historical development of unmanned aircraft systems (UAS). UAS have long performed aspects of their missions independently, such as by self-navigating through predefined waypoints selected by a human planner. Yet, the Air Force envisions the CCA performing far more sophisticated behaviors against deadlier adversaries.

Compared to past UAS, the distinguishing feature of CCAs will be their ability to collaborate both among themselves and with manned aircraft. For example, a manned aircraft pilot could assign CCAs to fly a forward sensing mission by maintaining specific positioning relative to an enemy aircraft, a directive requiring the CCAs to synchronize their movements without continually seeking the pilot's input.[7] The CCAs would thus self-coordinate while also taking any new commands from their pilot supervisor. According to Steven Fino, a former fighter pilot and scholar of military automation working at Collins Aerospace, "It's the CCAs' ability to collaborate amongst themselves to augment dynamic, human-level objectives that will be the game changer."[8]

Despite the CCA's promise, history is littered with UAS programs that offered technological breakthroughs but ultimately failed due to organizational resistance, cost growth, operational problems, or the emergence of alternative options (including manned aircraft) that offered better performance at lower cost.[9] Technological novelty does not guarantee becoming a fielded and impactful military capability.

Moving the CCA from promise to reality will require a staggering amount of difficult work stretching far into the future. To succeed, the Air Force must start with an honest accounting of what is required and where things stand.

Framework and Evidence

This report uses a new framework developed by the author—the end-to-end process cycle—to assess the CCA program's progress to date, presenting the findings as a stoplight chart. The framework consists of seven steps required to field a new military capability. The framework is designed to be a generalized model applicable to programs other than the CCA. Its strengths are that it combines insights from diverse research traditions and incorporates more factors than a typical program evaluation by, for instance, the Pentagon's Cost Assessment and Program Evaluation office.

7 Air Force, "Background Briefing on Collaborative Combat Aircraft," November 17, 2022, 10, https://www.af.mil/Portals/1/documents/1/CCA_Background_Briefing_Transcript_(final).pdf.

8 Author's communication with Steven Fino, August 27, 2024.

9 Thomas P. Ehrhard, *Air Force UAVs: The Secret History* (Arlington, VA: Mitchell Institute, July 2010).

The assessment relies on six major sources of evidence: (a) publicly available information; (b) briefings from Air Force officials; (c) confidential interviews and communication with over 30 industry experts; (d) a confidential survey of 38 experts from the Department of Defense, industry, and think tanks about affordable mass systems; (e) a historical case study of the AQM-34 Lightning Bug, a Vietnam War-era UAS highly relevant to CCA development;[10] and (f) analysis of CCA employment, basing, and sortie generation in a Taiwan scenario, published as a companion volume titled *No Dominant Strategy for Air Dominance*.[11]

With its novel framework and wide-ranging evidence, the report scrutinizes the CCA program in ways that no study has before. It advances CSBA's long-running work developing innovative approaches to defense analysis.[12]

Findings

The CCA program has made significant progress on defining the problem and generating resources, but it has fared less well on the develop, deploy, and employ steps (Table 1). These findings could be encouraging or concerning based on one's perspective. To optimists, the fact that earlier steps display more progress indicates the Air Force is hitting CCA milestones sequentially over time. If that continues, the results will look incrementally better in a year or two. To pessimists, the interdependence of the three steps with the most laggard progress (develop, deploy, employ) suggests those steps must improve together or not at all. If that is the case, then piecemeal progress has run its course. The Air Force now must improve everything everywhere all at once.

10 Joseph Ross, "The AQM-34 Lightning Bug's Lessons for the Collaborative Combat Aircraft," Center for Strategic and Budgetary Assessments (CSBA) working paper, December 2023.

11 Travis Sharp, *No Dominant Strategy for Air Dominance: Collaborative Combat Aircraft Employment, Basing, and Sortie Generation in a Taiwan Scenario* (Washington, DC: CSBA, May 2025).

12 Barry Watts, *Analytic Criteria for Judgments, Decisions, and Assessments* (Washington, DC: CSBA, 2017), https://csbaonline.org/uploads/documents/CSBA6271_(Analytic_Criteria_Report)_Web_3.pdf; Thomas G. Mahnken, ed., *Net Assessment and Military Strategy: Retrospective and Prospective Essays* (Amherst, NY: Cambria Press, 2020); and Evan Montgomery, Travis Sharp, and Tyler Hacker, "Quality Has a Quality All Its Own: The Virtual Attrition Value of Superior-Performance Weapons," *War on the Rocks*, June 19, 2024, https://warontherocks.com/2024/06/quality-has-a-quality-all-its-own-the-virtual-attrition-value-of-superior-performance-weapons/.

TABLE 1: END-TO-END ASSESSMENT OF CCA PROGRAM'S PROGRESS TO DATE

Step	Assessment	Rationale
1. Define problem Identify a capability gap that presents unacceptable operational risk if left unmitigated	Significant progress	Key stakeholders agree with the Air Force that its future manned aircraft fleet will face intolerable quantitative disadvantages against China's A2/AD network. The Air Force has successfully presented the CCA as a promising potential solution. Risks to this progress include senior leader turnover and potential developments in U.S.-China military competition.
2. Generate resources Begin accumulating budgetary, technological, human, and other resources required to produce the capability	Significant to moderate progress	The Air Force has dedicated significant funds to the CCA program and Congress has generally supported it. Future threats to resourcing include CCA costs exceeding expectations and CCAs being sacrificed to afford manned aircraft.
3. Develop capability Design a capability addressing defined problem given anticipated resource constraints (which may change)	Moderate to limited progress	The Air Force has rapidly advanced CCA capability. Congress has applauded its progress. However, it has hesitated to narrow down CCA combat roles, instead stressing usefulness across many missions—an emphasis that obscures the need for tradeoffs. Clinging to too many missions interferes with detailed work and progress on other steps.
4. Prepare organizations Integrate the capability into existing force and broader military structure	Moderate progress	The Air Force has worked steadily to build confidence in mission autonomy, a necessary condition for integrating CCAs into the force. Yet, there remain organizational obstacles to overcoming the unprecedented challenge of fielding highly capable autonomous systems. These include classification barriers to entry for industry and operator skepticism.
5. Deploy capability Position, control, and support the capability so that it can perform assigned tasks	Limited progress	The Air Force has released few details about CCA basing and sustainment. Fielding CCAs will place additional demands on operating locations, logistics, and alliance relationships already stressed by supporting manned aircraft in highly contested environments. Assuaging concerns about basing and sustainment should be a top priority in the near term.
6. Employ capability Use the capability to perform assigned tasks such as operating against enemy forces	Moderate to limited progress	The Air Force needs to make more progress with specifying CCA employment concepts. It should show and share its work so supportive outsiders understand the choices and tradeoffs it is making. The CCA has lived by analysis, but it can also die by analysis. Not all CCA assessments have met stakeholder expectations, leading them to question certain decisions.
7. Adapt practices Learn from operational experience and make adjustments that feed back into cycle	Moderate progress	The Air Force has committed to work iteratively with industry to improve CCAs based on technological advancements, experimentation, and operational experience. Although these commitments are encouraging, many details remain to be confirmed regarding the industrial base, contracting arrangements, and related matters.

Source: CSBA analysis.

The author sides with the optimists in believing the CCA program can succeed by continuing to make discrete progress. Pessimists are right about interdependent steps. Yet, expecting a global solution that turns the entire stoplight chart green in one stroke of genius is unrealistic. Criticizing the Air Force for lacking such a solution is unfair. The CCA is a novel capability. It is not a standard acquisition effort with an antecedent system to anchor planning on. It has advanced significantly in just two years. Conceptual breakthroughs often come in fits and starts. The Air Force can find workable approaches if it stays on target.

The CCA has come to symbolize the desire of nearly everyone to break free of the Pentagon's acquisition status quo.[13] Buoyed by this symbolism, the program will likely continue to receive the benefit of the doubt from its political overseers.[14] They will criticize and adjust it as they see fit. But they will not want to extinguish a capability that signifies what is, to many, the necessary direction for the future U.S. military. The CCA thus enjoys strong implicit political support. The Air Force has used this gift well. It must not relent.

13 National Defense Strategy (NDS) Commission Final Report, July 2024, 29–36, https://www.rand.org/nsrd/projects/NDS-commission.html; Shyam Sankar, *The Defense Reformation* (Denver, CO: Palantir, October 31, 2024), https://www.18theses.com/The%20Defense%20Reformation.pdf; and Roger Wicker, *Restoring Freedom's Forge: American Innovation Unleashed*, December 19, 2024, https://www.wicker.senate.gov/2024/12/senator-wicker-announces-pentagon-reform-and-innovation-proposal.

14 Dan Lamothe, Alex Horton, and Hannah Natanson, "Trump Administration Orders Pentagon to Plan for Sweeping Budget Cuts," *Washington Post*, February 19, 2025, https://www.washingtonpost.com/national-security/2025/02/19/trump-pentagon-budget-cuts/.

Two Larger Themes of the Assessment

Technology Is Never Enough

Harnessing new technology is necessary, but not sufficient, for the CCA program to succeed. The Air Force must devote attention to each step of getting the CCA from the drawing board to the enemy's doorstep. Observers may fixate on technology, as often occurs in the U.S. defense community. Technological progression is no doubt essential, particularly with mission autonomy. Yet, ultimate success requires addressing sustainment, basing, organization, and other matters that rarely capture headlines. As Lieutenant General David Harris, Air Force Futures deputy chief of staff, put it, "We tend to focus a lot on the materiel piece of this, but there is so much more baked into the doctrine, the [tactics, techniques, and procedures], the manpower piece of CCAs. All those things have to be thought through."[15] The Air Force has repeatedly innovated and excelled in these areas. It can do so again.

The Air Force should develop requirements and select solutions that demonstrate the highest performance across the end-to-end process of fielding CCAs. Industry offerings that support advantageous sustainment, basing, organization, and adaptation should receive preferential treatment over offerings that emphasize more limited criteria. The Air Force must drive industry to develop such offerings by issuing well-crafted requirements.

This admonition to look beyond technology may seem self-evident, but it bears repeating to an Air Force that still exhibits technology-first attitudes.[16] Ironically, the CCA program is one of the most technologically ambitious programs in Air Force history, but its ultimate success depends on nontechnological factors.

Tradeoffs: Now, Later, Always

There is no one-size-fits-all solution to CCA employment and design. In a future U.S.–China conflict over Taiwan, a CCA fleet conducting persistence missions in vicinity of Taiwan would need a different aircraft design, sustainment setup, and attrition reserve than a CCA fleet launching hit-and-run attacks outside Taiwan.[17] Unfortunately, Air Force public comments have obscured this problem of choice by stressing the CCA's usefulness across

15 Greg Hadley, "Will Unmanned Collaborative Combat Aircraft Mean Airmen Need New AFSCs?," *Air & Space Forces Magazine*, April 12, 2024, https://www.airandspaceforces.com/collaborative-combat-aircraft-airmens-jobs/.

16 As General Henry "Hap" Arnold once stated, "We must remember at all times that the degree of national security rapidly declines when reliance is placed on the *quantity* of existing equipment instead of its *quality*." Shannon L. C. Souma, "Inside the Blue Box: Organizational Identity and Turf Decision-Making in the United States Air Force" (PhD diss., Georgetown University, 2021), 172.

17 Sharp, *No Dominant Strategy*, chaps. 1 and 3.

many applications, thereby downplaying the fact that tradeoffs must be made to excel at any given mission.[18]

Although flexibility is desirable, today's force planners must make choices that tie the hands of future service members in one way or another. In the real world of resource constraints and opportunity costs, one cannot keep all options on the table.

The Air Force should make the best decisions about CCA employment and design that it can, as soon as it can, and communicate them as widely as it can. Making tradeoffs today, even if proven imperfect later, is better than deferring decisions in search of optimal solutions that may never come. The future Air Force can still prevail without being dealt the perfect hand by today's force planners. It has done exactly that in the past. But it cannot win if it does not have cards to play.

18 Air & Space Forces Association Warfare Symposium, "Advancements in Collaborative Combat Aircraft CONOPs," 2; and Air Force, *PACAF Strategy 2023: Evolving Airpower*, September 2023, 9, https://www.af.mil/Portals/1/documents/2023SAF/PACAF_Strategy_2030.pdf.

CHAPTER 1

From Promise to Program: Collaborative Combat Aircraft Overview

The collaborative combat aircraft (CCA) exemplifies a new phase in the historical development of unmanned aircraft systems (UAS). UAS have long performed aspects of their missions independently, such as by self-navigating through predefined waypoints selected by a human planner. The AQM-34 Lightning Bug, a Vietnam War-era UAS, operated in this fashion (Table 2). In recent times, the RQ-4 Global Hawk has demonstrated the ability to conduct intricate autonomous operations.[19] Yet, the Air Force envisions the CCA performing far more sophisticated autonomous behaviors against deadlier adversaries.[20]

19 Jonathan E. Skillings, "Global Hawk Closer to Autonomous Aerial Refueling," *CBS News*, March 10, 2011, https://www.cbsnews.com/news/global-hawk-closer-to-autonomous-aerial-refueling/.

20 An autonomous weapons system "once activated, can select and engage targets without further intervention by an operator. This includes, but is not limited to, operator-supervised autonomous weapon systems that are designed to allow operators to override operation of the weapon system, but can select and engage targets without further operator input after activation." Department of Defense (DoD), "Autonomy in Weapon Systems," DoD Directive 3000.09, January 25, 2023, 21, https://www.esd.whs.mil/portals/54/documents/dd/issuances/dodd/300009p.pdf.

TABLE 2: SIX PHASES IN THE HISTORICAL DEVELOPMENT OF UAS

	Key developments	Key systems
Phase 1 Proto-innovation and concept development, 1849–1930s	Early attempts to use UAS for rudimentary strike operations largely failed, although they hinted at a future capability.	Balloon bomb Kettering Bug
Phase 2 New technologies enable new missions, World War 2	Evolution in propulsion, remote control, and targeting created new opportunities for UAS not only as targeting drones but also for strike missions.	De Haviland Queen Bee Radioplane OQ-2
Phase 3 Intelligence, surveillance, and reconnaissance (ISR) revolution, World War 2 through Vietnam War	Advances in cameras, propulsion, encryption, and launch and recovery systems increased the practicality of UAS. Momentum created by the AQM-34 Lightning Bug during the Vietnam War dissipated as the war ended.	BQM-34 Firebee AQM-34 Lightning Bug
Phase 4 Stalled momentum and periodic experimentation, post-Vietnam War through late 1990s	Development of ISR technologies, including real-time video feeds, attracted investment in UAS, which operated in the Arab–Israeli conflicts and Gulf War.	Scout Pioneer Shadow Tacit Rainbow
Phase 5 Demonstrating value, late 1990s through global counterterrorism wars	Improvements in payloads, communications systems, laser designators, aircraft endurance, and weapons systems allowed fielding of multimission, high-altitude UAS in permissive environments. Global interest in UAS grew as systems demonstrated value in diverse contexts.	Predator Reaper Global Hawk
Phase 6 Velocity, volume, and variety, present day	Innovations in autonomy, human–machine teaming, low observability, miniaturization, and data fusion have increased the sophistication and potential applications for UAS. The convergence of commercial and military technologies has enabled production of greater quantities, which can help lower unit costs.	Black Hornet Raven DJI Phantom CCA

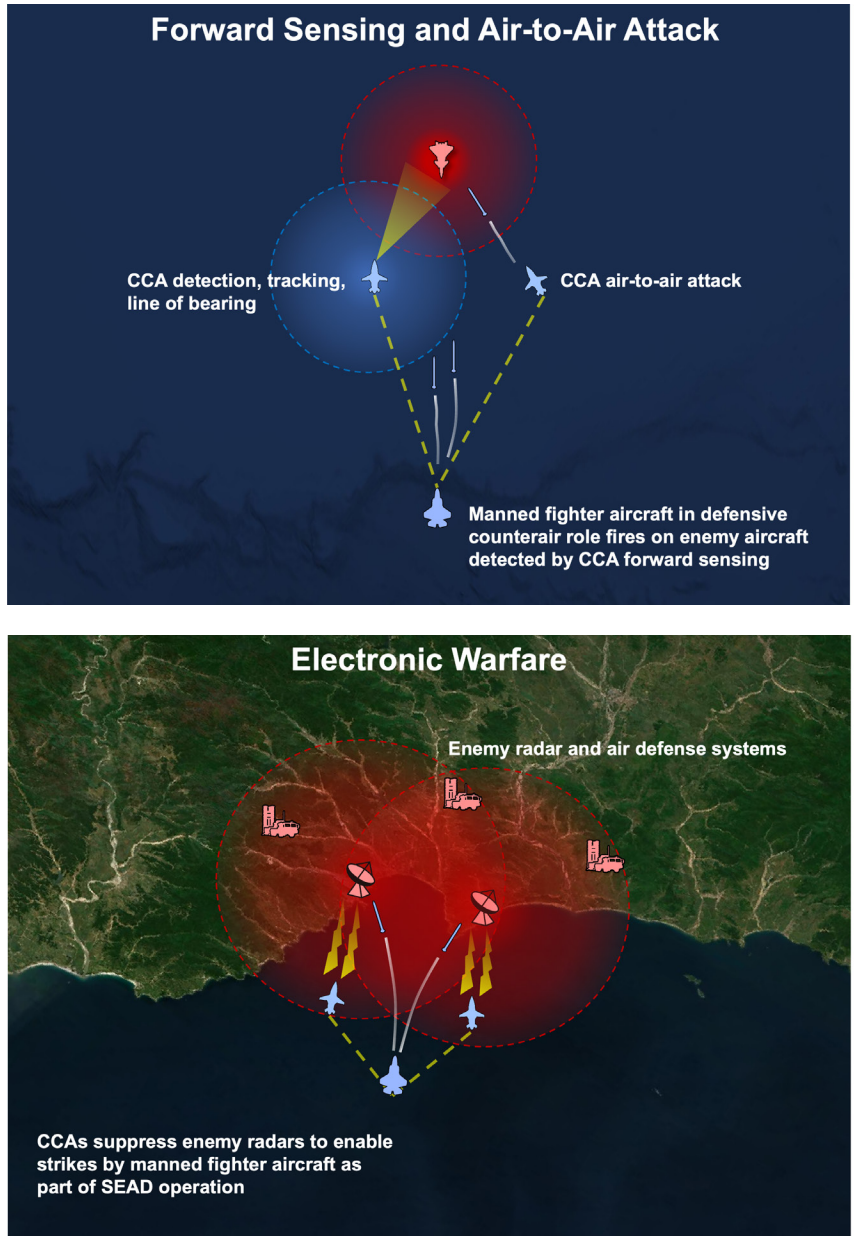
Source: CSBA analysis. Framework developed by Tate Nurkin.

Compared to previous UAS, the distinguishing feature of CCAs will be their ability to collaborate both among themselves and with manned aircraft (Figure 1). For example, a manned aircraft pilot could direct assigned CCAs to fly a forward sensing mission while maintaining specific positioning relative to an enemy combat aircraft, a directive requiring the CCAs to synchronize their movements without continually seeking the pilot's input.[21] The CCAs would thus self-coordinate while taking new commands from their pilot supervisor.

21 Air Force, "Background Briefing on Collaborative Combat Aircraft," November 17, 2022, 10, https://www.af.mil/Portals/1/documents/1/CCA_Background_Briefing_Transcript_(FINAL).pdf.

According to Steven Fino, a retired fighter pilot and scholar of military automation currently working at Collins Aerospace, "It's the CCAs' ability to collaborate amongst themselves to augment dynamic, human-level objectives that will be the game changer."[22]

FIGURE 1: ILLUSTRATIVE CCA COMBAT MISSIONS



Source: CSBA analysis.

22 Author's communication with Steven Fino, August 27, 2024. See Steven A. Fino, *Tiger Check: Automating the U.S. Air Force Fighter Pilot in Air-to-Air Combat, 1950–1980* (Baltimore: Johns Hopkins University Press, 2017).

If fielded as envisioned, future CCAs would provide novel options for forward sensing, air-to-air attack, and electronic warfare.[23] In forward sensing, CCAs could assume risks the manned fighter would prefer to avoid by flying ahead into the enemy threat envelope, establishing picket positions, and sending back threat tracking information.[24] In air-to-air attack, CCAs could, under the fighter's direction, launch missiles at enemy aircraft, effectively extending the fighter's weapons engagement zone beyond its own onboard munitions. In electronic warfare, CCAs could not only send back threat tracking information but also degrade enemy radar in advance of fighter missile strikes. In all these missions, enemy reconnaissance might struggle to distinguish the CCAs from the fighter, creating confusion about which aircraft to attack. This would result in suboptimal enemy targeting of CCAs instead of more valuable manned fighters.[25]

The Air Force envisions the CCA fleet creating "a distributed, mission-tailorable mix of sensors, weapons, and other mission equipment" that would enable manned aircraft to fire and maneuver against enemies in new ways.[26] As retired Air Force Major General Scott Jobe, a former program leader, remarked, the CCA brings "opportunity for tactics, techniques, and procedures development, with different kinds of scheme of maneuver [and] with a different firepower that's really not been seen before."[27]

The Air Force is not alone in seeing the promise of autonomous combat UAS. The Navy has its own CCA program, and numerous U.S. allies and potential adversaries also have initiated loyal wingman UAS efforts (Table 3). The Air Force has shared CCA information with the Navy, as well as with Australia and the United Kingdom, to promote interoperability across different initiatives.[28] According to *Janes*, the global market for loyal wingman UAS through 2031 will include sales of over 2,000 air vehicles with an estimated value of $2.3 billion.[29]

23 Stephen Losey, "U.S. Air Force Eyes Fleet of 1,000 Drone Wingmen as Planning Accelerates," *Defense News*, March 8, 2023, https://www.defensenews.com/air/2023/03/08/us-air-force-eyes-fleet-of-1000-drone-wingmen-as-planning-accelerates/.

24 Joseph Trevithick, "B-21 Raider Could Use Collaborative Drones Meant for Fighters," *The War Zone*, September 6, 2023, https://www.thedrive.com/the-war-zone/b-21-raider-could-partner-with-collaborative-drones-meant-for-fighters.

25 Valerie Insinna, "Coming Soon: A U.S. Competition for Sixth-Gen Drone Wingman Could Begin in FY24," *Breaking Defense*, September 7, 2022, https://breakingdefense.com/2022/09/coming-soon-a-us-competition-for-sixth-gen-drone-wingman-could-begin-in-fy24/.

26 Air Force Scientific Advisory Board, "Collaborative Combat Aircraft for Next Generation Air Dominance," 2022, 1, https://www.scientificadvisoryboard.af.mil/Portals/73/DAF%20SAB%20FY22%20Study%20ToRs_SecAF%20Final.pdf; and Air & Space Forces Association Warfare Symposium, "Advancements in Collaborative Combat Aircraft CONOPs," March 8, 2023, 8, https://www.afa.org/app/uploads/2023/12/Advancements-in-Collaborative-Combat-Aircraft-CONOPs-Transcript.pdf.

27 John A. Tirpak, "Air Force Touts Unity of Effort in Push Toward New Collaborative Combat Aircraft," *Air & Space Forces Magazine*, November 17, 2022, https://www.airandspaceforces.com/air-force-touts-unity-of-effort-in-push-toward-new-ccas-collaborative-combat-aircraft/.

28 Air Force, "Background Briefing," 13–14.

29 Gareth Jennings, "Disposable Heroes: Rise of the Attritable Loyal Wingmen," *Janes*, February 16, 2022.

TABLE 3: NOTABLE LOYAL WINGMAN UAS PROGRAMS WORLDWIDE

	Key activities
China	China's investments in swarming capabilities have received more attention than its work on loyal wingman technology, but it has developed multiple UAS that could team with manned aircraft. In September 2021, the state-owned China Aerospace Science and Technology Corporation revealed a prototype of the FH-97 loyal wingman UAS.[30] In November 2024, an updated FH-97A prototype featured an enhanced weapons bay and the ability to launch from aircraft carriers.[31] China has also experimented with manned–unmanned teaming using the stealthy GS-11 Sharp Sword UAS.[32] Some observers believe the LJ-1 target drone could also serve as a loyal wingman.[33]
Russia	Russia is developing the Grom and Okhotnik UAS to team with manned fighters.[34] Both programs support a broader Russian effort to modernize its UAS industry and capability across several categories of systems. In June 2023, unverified open-source reports suggested the Okhotnik may have flown in Ukraine.[35]
Australia	The Boeing Australia MQ-28A Ghost Bat loyal wingman prototype, previously known as the Air Power Teaming System, completed its first test flight in February 2021.[36] Boeing Australia has a contract to produce 10 MQ-28As for development and testing, and the Australian government has called for accelerating the program.[37] Australia and the United States have signed an agreement to share classified information about the MQ-28A's sensors, teaming behavior, and data links.

30 David Kirton, "China Unveils 'Loyal Wingman' Armed Drone Concept," *Reuters,* September 29, 2021, https://www.reuters.com/business/aerospace-defense/china-unveils-loyal-wingman-armed-drone-concept-2021-09-29/; and Thomas Newdick and Tyler Rogoway, "China Is Cloning Kratos' XQ-58A Valkyrie Unmanned Combat Air Vehicle Concept (Updated)," *The War Zone,* September 29, 2021, https://www.twz.com/42555/china-is-cloning-kratos-xq-58a-valkyrie-unmanned-combat-air-vehicle-concept.

31 William Langley and Joe Leahy, "China's 'Loyal Wingman' Drones Open New Front in Military Competition with U.S.," *Financial Times*, December 15, 2024, https://www.ft.com/content/5687a223-6115-4cbc-86d2-2e17aaa54dc1.

32 Franz-Stefan Gady, "How Chinese Unmanned Platforms Could Degrade Taiwan's Air Defense and Disable a U.S. Navy Carrier," *The Diplomat*, June 8, 2021, https://thediplomat.com/2021/06/how-chinese-unmanned-platforms-could-degrade-taiwans-air-defense-and-disable-a-us-navy-carrier/.

33 Kyle Mizokami, "China's Loyal Wingman Drone Flies Alongside Manned Fighters," *Popular Mechanics,* August 31, 2019, https://www.popularmechanics.com/military/aviation/a28845055/china-loyal-wingman-drone/.

34 Valius Venckunas, "Closer Look at Grom, the Russian Loyal Wingman," *Aerotime Hub*, September 12, 2020, https://www.aerotime.aero/25876-closer-look-at-grom-the-russian-loyal-wingman.

35 Vijainder K. Thakur, "Russia's S-70 Okhotnik Heavy Stealth Drone Starts Bashing Ukrainian Forces as Kyiv Desperately Awaits F-16s," *EurAsian Times*, July 1, 2023, https://www.eurasiantimes.com/russias-s-70-okhotnik-heavy-stealth-drone-starts-bashing/.

36 Greg Waldron, "Australian 'Loyal Wingman' to Form Basis of Boeing Skyborg Effort," *FlightGlobal*, March 2, 2021, https://www.flightglobal.com/defence/australian-loyal-wingman-to-form-basis-of-boeing-skyborg-effort/142689.article.

37 Nigel Pittaway, "Government Accelerates Ghost Bat Program," *Australian Defence Magazine*, July 14, 2023, https://www.australiandefence.com.au/news/government-accelerates-ghost-bat-program.

France, Germany, and Spain	France, Germany, and Spain are jointly pursuing a Future Combat Air System (FCAS/SCAF) program featuring recoverable and expendable "remote carrier" UAS.[38] The FCAS system of systems, which includes a next-generation fighter and combat cloud architecture, is scheduled to enter service in the mid-2040s.[39]
India	State-owned Hindustan Aeronautics Limited revealed its Combat Airpower Teaming System (CATS) in February 2021. The program consists of systems designed to team with manned aircraft, including a stealthy loyal wingman UAS (CATS Warrior), an air-launched cruise missile (CATS Hunter), an unmanned carrier system capable of launching loitering munitions (CATS ALFA), and a high-altitude pseudosatellite for ISR and communications (CATS Infinity).[40] CATS Warrior is scheduled to begin flight testing in late 2024 or early 2025.[41]
Japan	Japan has partnered with the United Kingdom and Italy to pursue the Global Combat Air Programme (GCAP), an initiative designed to produce Japan's sixth-generation manned fighter (Mitsubishi F-X) supported by loyal wingman-style UAS.[42] Japan has worked on autonomous UAS technology for years through its Combat Support Unmanned Aircraft program, which is scheduled to deliver a prototype in 2025.[43]
United Kingdom	The United Kingdom is playing a leading role in several autonomous UAS development efforts. Besides the GCAP partnership with Japan and Italy, which will produce the UK's sixth-generation fighter (BAE Tempest), the UK has also worked for years on its own Future Combat Air System initiative (not to be confused with the separate France–Germany–Spain FCAS) to develop a mix of manned and unmanned platforms, including swarming drones.[44]

Source: CSBA analysis.

A Critical Summary of CCA Plans

History is littered with UAS programs that promised technological breakthroughs but ultimately failed due to organizational resistance, cost growth, operational problems, or the

38 David Donald, "FCAS Expendable Remote Carrier on Course for 2029 Demo," *Aviation International*, June 21, 2023, https://www.ainonline.com/aviation-news/defense/2023-06-21/fcas-expendable-remote-carrier-course-2029-demo.

39 Nigel Torp Petersen, "Paris Air Show 2023: MBDA Announces New FCAS Effector Programme," *Janes*, June 22, 2023.

40 "HAL Working on Manned-Unmanned Combat Air Teaming System," *Indian Military Review*, July 25, 2022, https://imrmedia.in/hal-working-on-manned-unmanned-combat-air-teaming-system/.

41 Akhil Kadidal, "HAL Loyal Wingman Project to Go Airborne by 2024," *Janes*, March 23, 2022.

42 Richard Thomas, "New GCAP Fighter Moves beyond Parochial European Continentalism," *Airforce Technology*, December 9, 2022, https://www.airforce-technology.com/features/new-gcap-fighter-moves-beyond-parochial-european-continentalism/.

43 Valius Venckunas, "Loyal Wingmen: The Cyberpunk Future of Aerial Warfare," *Aerotime Hub*, March 30, 2023, https://www.aerotime.aero/articles/25825-loyal-wingmen-the-cyberpunk-future-of-aerial-warfare.

44 Tim Martin, "FCAS? SCAF? Tempest? Explaining Europe's Sixth-Generation Fighter Efforts," *Breaking Defense*, June 16, 2023, https://breakingdefense.com/2023/06/fcas-scaf-tempest-explaining-europes-sixth-generation-fighter-efforts/; and UK Ministry of Defence, *Defence in a Competitive Age*, March 2021, 56, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/974661/CP411_-Defence_Command_Plan.pdf.

emergence of alternative options (including manned aircraft) that offered better performance at lower cost.[45] Technological novelty does not guarantee becoming a fielded and impactful military capability. Transforming the CCA's promise into a coherent program is forcing the Air Force to confront difficult choices about inventory, cost, and design.

Inventory

In 2023, Air Force Secretary Frank Kendall proposed a future inventory of around 1,000 CCAs, describing that figure as "a reasonable starting point" that could increase twofold or more.[46] The 1,000 aircraft figure is based on the notional assumption that 200 Next Generation Air Dominance (NGAD) manned fighter aircraft and 300 F-35s would be assigned at least two CCAs apiece.[47] Air Force officials said CCAs might also be controlled from B-21 bombers, F-15EX fighters, E-7 airborne early warning and control aircraft, KC-46 refueling tanker aircraft, or ground stations.[48]

Initially, the Air Force stressed that fielding CCAs would not affect the planned manned fighter inventory.[49] Later, however, Kendall conceded, "It's hard for me to see how we can afford any combination" of the CCAs, NGAD manned fighters, and next-generation refueling tankers that the Air Force wants to acquire.[50] Chapter 3 considers affordability in more detail.

Cost

In 2023, the Air Force announced a CCA cost target of one quarter to one half of the F-35's current cost, equaling roughly $20 million to $40 million per CCA. It later revised that target down to one quarter to one third of the F-35's cost ($20 million to $30 million).[51]

45 Thomas P. Ehrhard, *Air Force UAVs: The Secret History* (Arlington, VA: Mitchell Institute, July 2010).

46 Michael Marrow, "Next Gen Numbers: Air Force Plans First 'Nominal' Buy of 200 NGAD Fighters, 1,000 Drone Wingmen," *Breaking Defense*, March 7, 2023, https://breakingdefense.com/2023/03/air-force-plans-nominal-buy-of-200-ngad-fighters-1000-drone-wingmen-kendall-says/; and John A. Tirpak, "Kendall: Air Force Wants as Many as 2,000 CCAs with a Common, Modular Airframe," *Air & Space Forces Magazine*, March 16, 2023, https://www.airandspaceforces.com/kendall-air-force-2000-ccas-common-modular-airframe/.

47 Previously, Kendall said a manned aircraft might control up to five CCAs. Briana Reilly, "With Combat Drone Programs Forthcoming, Transition of 'Technology Feeders' Unclear," *Inside Defense*, March 24, 2022.

48 Joseph Trevithick, "200 NGAD Fighters, 1,000 Advanced Drones in USAF's Future Plans," *The War Zone*, March 7, 2023, https://www.thedrive.com/the-war-zone/200-ngad-fighters-1000-advanced-drones-in-usafs-future-plans; and John A. Tirpak, "Brown: Collaborative Combat Aircraft Not Just for NGAD," *Air & Space Forces Magazine*, August 29, 2022, https://www.airandspaceforces.com/brown-collaborative-combat-aircraft-not-just-for-ngad/.

49 Marrow, "Next Gen Numbers."

50 Stephen Losey, "Next-Gen Stealth Tanker May Be Unaffordable, Air Force Secretary Fears," *Defense News*, November 8, 2024, https://www.airforcetimes.com/air/2024/11/08/next-gen-stealth-tanker-may-be-unaffordable-air-force-secretary-fears/.

51 John A. Tirpak, "Collaborative Combat Aircraft Will Join the Air Force Before NGAD," *Air & Space Forces Magazine*, March 29, 2023, https://www.airandspaceforces.com/collaborative-combat-aircraft-ngad-timeline/; and Jospeh Trevithick and Tyler Rogoway, "Signs Point to Less Range, Higher Performance for CCA Drones," *The War Zone*, November 28, 2023, https://www.thedrive.com/the-war-zone/signs-point-to-less-range-higher-performance-for-cca-drones.

The service consistently stressed that these ranges represented preliminary estimates, not fixed requirements. More recently, the Air Force has emphasized an even lower target of $10 million or less for the initial tranche of CCAs, according to industry experts.[52]

This shifting price point helps explain why the Air Force opposed a 2023 attempt by Congress to enshrine CCA cost targets in law.[53] The service clearly has not settled on how much initial and future CCA variants should cost, so it did not want Congress to tie its hands.

The Air Force wants to keep the CCA's cost down because it plans on aircraft being lost in battle. Kendall expressed concern about CCAs becoming "gold plated" and excessively expensive.[54] As he remarked, "To have an affordable Air Force of a reasonable size, we've got to introduce some lower cost platforms."[55]

Official and public commentary has focused primarily on the CCA's per unit airframe cost. However, many studies have highlighted the large additional costs that could materialize depending on future decisions about basing, manning, and sustainment.[56] Additionally, the mission autonomy systems onboard the CCA will require significant investment that is not fully reflected in the cost figures that have been publicly discussed. Chapter 3 covers each of these issues in more depth.

Design

The CCA's ultimate cost will depend on its range, survivability, speed, payload, onboard mission systems, expected service life, and other factors. Tradeoffs among these factors are

52 Author's communication with industry experts from traditional defense firm, September 11, 2024.

53 John A. Tirpak, "Air Force 'Very Opposed' to Lawmakers' Proposed Cost Limits for CCAs," *Air & Space Forces Magazine*, September 12, 2023, https://www.airandspaceforces.com/air-force-very-opposed-cost-limits-ccas/.

54 Joseph Trevithick, "'Affordable Mass' Concept Driving Air Force's New Advanced Drone Initiative," *The War Zone*, March 10, 2023, https://www.thedrive.com/the-war-zone/affordable-mass-concept-driving-air-forces-new-advanced-drone-initiative.

55 Abraham Mahshie, "Kendall: Air Force Has an 'Affordability Problem' as It Tries to Meet Capability Gap," *Air & Space Forces Magazine*, June 1, 2022, https://www.airandspaceforces.com/kendall-air-force-has-an-affordability-problem-as-it-tries-to-meet-capability-gap/.

56 James A. Leftwich, Bradley DeBlois, and David T. Orletsky, *Supporting Combat Power Projection away from Fixed Infrastructure* (Santa Monica, CA: RAND Corporation, 2022), https://www.rand.org/pubs/research_reports/RRA596-1.html; Justin Bronk, "Swarming Munitions, UAVs and the Myth of Cheap Mass," *Whitehall Papers* 99, no. 1, December 2021, 49–60; Chris Dougherty, *More Than Half the Battle: Information and Command in a New American Way of War* (Washington, DC: Center for a New American Security, May 2021), 38, https://s3.amazonaws.com/files.cnas.org/CNAS+Report-Command+and+Info-2021.pdf; Thomas Hamilton, *Comparing the Cost-Effectiveness of Expendable Versus Reusable Small Air Vehicles* (Santa Monica, CA: RAND Corporation, 2021), https://www.rand.org/pubs/research_reports/RR2789.html; Thomas Hamilton and David Ochmanek, *Operating Low-Cost, Reusable Unmanned Aerial Vehicles in Contested Environments: Preliminary Evaluation of Operational Concepts* (Santa Monica, CA: RAND Corporation, 2020), https://www.rand.org/content/dam/rand/pubs/research_reports/RR4400/RR4407/RAND_RR4407.pdf; and R.H. Jacobson, *Low Cost Tactical RPVs* (Santa Monica, CA: RAND Corporation, 1972), https://www.rand.org/pubs/papers/P4902.html.

required to field an aircraft meeting the Air Force's inventory and cost goals.[57] Air Force officials have said they have drafted these types of requirements and feel confident about them—but the full details remain classified.[58] To date, the Air Force has publicly disclosed information about several potential CCA features.

- **Engine:** In September 2023, the Air Force released a request for information about potential CCA engine options in the 3,000–8,000 pound thrust class that is typically used by light military jets or commercial business jets.[59] The request aimed to explore design tradeoffs related to increased range, speed, thermal capacity, and payload.

- **Runway takeoff**: The September 2023 notice mentioned "reduced runway take-off distance," suggesting the Air Force wants CCAs to use runways rather than relying on alternative, nonrunway takeoff and landing methods such as rocket-assisted takeoff, a land-based electromagnetic aircraft launch system, or parachute recovery.[60]

- **Air-to-air refueling**: In November 2023, the Air Force stated that CCAs will probably be capable of air-to-air refueling and that the first aircraft produced could offer that capability, depending on industry offerings.[61] Observers often think of CCAs as fuel receivers, but they could also function as fuel suppliers if variants were designed to be CCA tankers.

- **Range**: In November 2023, Thomas Lawhead, head of Air Force Futures, said, "In the initial tranche of CCAs, their range will be relatively the same as our current fighter fleet. [It could even] potentially be a little bit longer, which helps with the flexibility of how we would actually employ them."[62] Lawhead's statement suggests that the first CCAs could feature a range on par with the F-35's unrefueled combat radius.

Air Force officials have emphasized that the CCA is not "an attritable type of platform."[63] Instead, they have characterized it as enhancing the capability of manned aircraft and

57 David E. Walker, testimony during hearing on "Fiscal Year 2017 Air Force Science and Technology," Subcommittee on Emerging Threats and Capabilities, House Armed Services Committee, February 24, 2016, 7, https://docs.house.gov/meetings/AS/AS26/20160224/104518/HHRG-114-AS26-Wstate-WalkerD-20160224.pdf.

58 Air Force, "Background Briefing," 6.

59 Air Force Materiel Command, *Future Collaborative Combat Aircraft (CCA) RFI*, Notice ID LPA-23-CCA, September 29, 2023, 3, https://sam.gov/opp/f5c515f38c0b4245a8013e788c7827f7/view; and Joseph Trevithick, "Future Air Combat Drone Performance Focus Areas Emerge," *The War Zone*, October 2, 2023, https://www.thedrive.com/the-war-zone/collaborative-combat-aircraft-performance-focus-areas-emerge.

60 Air Force Materiel Command, *Future Collaborative Combat Aircraft (CCA) RFI.*

61 Trevithick and Rogoway, "Signs Point to Less Range."

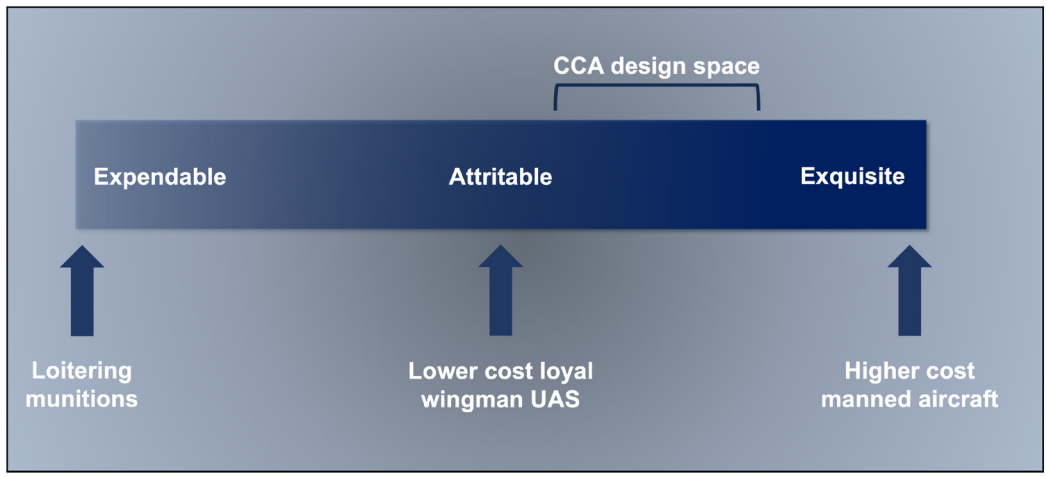
62 Trevithick and Rogoway, "Signs Point to Less Range."

63 Trevithick, "'Affordable Mass' Concept." An attritable aircraft is one "at a low-cost price point where there is increased tolerance for losing the asset to achieve a military objective. Systems that are attritable may be designed to a higher single-flight probability of failure and have lower expectations for total service-life. An attritable vehicle is designed to be reusable." Air Force Research Laboratory (AFRL), *Skyborg Autonomous Unmanned Combat Air Vehicle*, Notice ID FA8650-19-S-9340, updated October 21, 2019, 8, https://sam.gov/opp/f0ff3bf72e8142c7be57788c940ef9bd/view.

supplying "affordable mass [that] provides us an overmatch capability and changes our loss–exchange ratios dramatically in our favor" in high-end combat.[64] Because the Air Force does not regard CCAs as attritable, the CCA program does not fall under the Replicator initiative, a Pentagon effort unveiled in August 2023 to produce thousands of attritable autonomous aircraft, ships, and other systems within 18–24 months.

The CCA's currently envisioned capability falls along the center-right side of a spectrum running from expendable to attritable to exquisite, with each of these terms relating to an aircraft's maintainability, reliability, performance, and cost (Figure 2).[65] To borrow a previous study's analogy, an expendable aircraft is like a paper drinking cup, an attritable aircraft is like a red plastic Solo© cup, and an exquisite aircraft is like crystal glassware.[66] That makes the CCA, in the Air Force's view, something like a sturdy tumbler—not necessarily used every day or everywhere, but a compelling complement to costlier glassware when there are lots of thirsty guests.

FIGURE 2: CCA POSITION IN AIRCRAFT DESIGN SPACE



Source: CSBA analysis.

The Air Force may pursue future CCA variants that it considers attritable. Its initial variants may fall closer to the attritable category, even if the Air Force does not use that term, than future variants offering greater capability at a higher price.[67] Chapter 3 says more about aircraft design and tradeoffs.

64 Trevithick, "'Affordable Mass' Concept."

65 John Colombi et al., "Attritable Design Trades: Reliability and Cost Implications for Unmanned Aircraft," *IEEE Xplore*, May 2017, https://ieeexplore.ieee.org/abstract/document/7934767.

66 Colombi et al., "Attritable Design Trades," 1.

67 John A. Tirpak, "Kendall: CCA Increment 2 Shouldn't Be 'Exquisite,' but Better Than Increment 1," *Air & Space Forces Magazine*, January 8, 2025, https://www.airandspaceforces.com/kendall-cca-increment-2-exquisite/.

Conclusion

Moving the CCA from promise to reality will require a staggering amount of difficult work stretching far into the future. The Air Force has been tackling this work for years, but it is closer to the beginning than the end.[68] The good news is that the Air Force has faced daunting technical and operational challenges before, and it has prevailed.[69] It can do so again with the CCA, but the path will not be easy. To succeed, the Air Force must start with an honest accounting of what is required and where things stand. The next two chapters contribute to that accounting by introducing and applying the end-to-end process cycle framework to assess the CCA program's progress to date.

68 Gregory C. Allen and Isaac Goldston, *The Department of Defense's Collaborative Combat Aircraft Program: Good News, Bad News, and Unanswered Questions* (Washington, DC: Center for Strategic and International Studies [CSIS], August 2024), 4, https://www.csis.org/analysis/department-defenses-collaborative-combat-aircraft-program-good-news-bad-news-and.

69 Jacob Neufeld, *The Development of Ballistic Missiles in the United States Air Force, 1946–1960* (Washington, DC: Office of Air Force History, 1990), https://apps.dtic.mil/sti/tr/pdf/ADA439957.pdf.

CHAPTER 2

End-to-End Process Cycle: A Generalized Framework

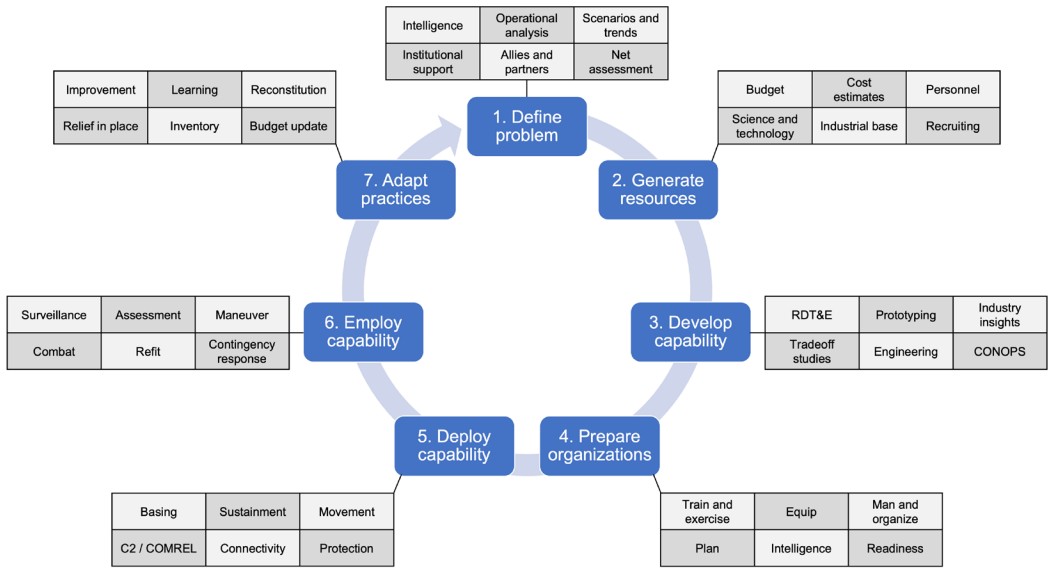
The successful fielding of a new military capability often follows similar steps. For this report, the author devised the end-to-end process cycle (E2EPC) to model the sequence expected to unfold over time. The cycle is a heuristic for thinking through the necessary conditions for success. It is not a blueprint for planning activities. The cycle consists of seven steps.

1. **Define problem**: Identify a capability gap that presents unacceptable operational risk if left unmitigated.[70]
2. **Generate resources**: Begin accumulating budgetary, technological, human, and other resources required to produce the capability.
3. **Develop capability**: Design a capability (plus an associated concept of operations) that addresses the operational problem given anticipated resource constraints (which may change).
4. **Prepare organizations**: Integrate the capability into existing force and broader military structure.
5. **Deploy capability**: Position, control, and support the capability so it can perform assigned tasks.
6. **Employ capability**: Use the capability to perform assigned tasks such as operating against enemy forces.
7. **Adapt practices**: Learn from operational experience and make adjustments that feed back into the cycle.

70 Defense Acquisition University, "Initial Capabilities Document (ICD)," n.d., https://www.dau.edu/acquipedia-article/initial-capabilities-document-icd.

Each step includes numerous interrelated activities (Figure 3). The activities will unfold and repeat across multiple steps, meaning the listed activities are merely illustrative. For example, intelligence analysis will happen throughout all stages.

FIGURE 3: END-TO-END PROCESS CYCLE DETAILED VIEW



Notes: Listed activities are not exhaustive.

The E2EPC framework synthesizes insights from the Department of Defense (DoD) Joint Capabilities Integration and Development System with research on military innovation, military power creation, and kill-chain models of sequential operations.[71]

Scholars have analyzed how countries create military power by extracting human, natural, and financial resources from the societies and territories they govern. The threat of war drives these extractive activities, which in turn shape the state's conduct of war.[72] In his study of America's Cold War grand strategy, Aaron Friedberg detailed how anti-statist influences in U.S. political culture counterbalanced the drive for manpower, money, technology, and weapons viewed as essential to military preparedness.[73] Scholarly treatments

71 Joint Staff, *Charter of the Joint Requirements Oversight Council and Implementation of the Joint Capabilities Integration and Development System*, CJCSI 5123.01I, October 30, 2021, https://www.jcs.mil/Portals/36/Documents/Library/Instructions/CJCSI%205123.01I.pdf; Adam Grissom, "The Future of Military Innovation Studies," *Journal of Strategic Studies* 29, no. 5, 2006, 905–934; Michael A. Hunzeker, *Dying to Learn: Wartime Lessons from the Western Front* (Ithaca, NY: Cornell University Press, 2021); and Kendrick Kuo, "Dangerous Changes: When Military Innovation Harms Combat Effectiveness," *International Security* 47, no. 2, Fall 2022, 48–87.

72 Charles Tilly, ed., *The Formation of National States in Western Europe* (Princeton: Princeton University Press, 1975).

73 Aaron L. Friedberg, *In the Shadow of the Garrison State: America's Anti-Statism and Its Cold War Grand Strategy* (Princeton: Princeton University Press, 2000), 3–4, 62–64.

like Friedberg's indicate resource inputs undergird military capability but are always constrained in one way or another.[74]

Defense policy experts have assessed military campaigns by breaking them down into sequential steps or streams of activities required to achieve an objective.[75] Phasing tasks over time is exemplified by many doctrinal concepts, including the Air Force's dynamic kill-chain model of find, fix, track, target, engage, and assess.[76] Over the years, RAND helped formalize the end-to-end method, with Ted Warner, Glenn Kent, and David Thaler often credited for pioneering work in this area.[77] Regardless of who developed the approach, impactful defense assessments frequently scrutinize interrelated operations over time to identify potential weaknesses.[78] If left unaddressed, these weaknesses might become show stoppers that impede success.[79]

The E2EPC framework has two features that make it useful. First, it combines insights from diverse research communities spanning scholarship and policy. These communities may not know each other's work and thus may not realize they are tackling similar problems and can learn from one another. For example, an international relations scholar studying states' historical failures to internally balance against threatening revisionist powers might

74 Rosella Cappella Zielinski, *How States Pay for Wars* (Ithaca, NY: Cornell University Press, 2016); Sarah E. Kreps, *Taxing Wars: The American Way of War Finance and the Decline of Democracy* (New York: Oxford University Press, 2018); and Paul Poast, "Beyond the 'Sinew of War': The Political Economy of Security as a Subfield," *Annual Review of Political Science* 22, 2019, 223–239.

75 Mark A. Gallagher and Philip Whiteman, "Probability Distribution Function for Damage Expectancy," *Military Operations Research Journal* 9, no. 3, 2004, 5.

76 Air Force, *Doctrine Publication 3-60: Targeting*, November 12, 2021, 27–30, https://www.doctrine.af.mil/Portals/61/documents/AFDP_3-60/3-60-AFDP-TARGETING.pdf.

77 Edward L. Warner III and Glenn A. Kent, *A Framework for Planning the Employment of Air Power in Theater War* (Santa Monica, CA: RAND Corporation, 1984), 12, https://www.rand.org/pubs/notes/N2038.html; David E. Thaler, *Strategies to Tasks: A Framework for Linking Means and Ends* (Santa Monica, CA: RAND Corporation, 1993), 13, https://www.rand.org/pubs/monograph_reports/MR300.html; David Ochmanek, Bruce Pirnie, and Michael Spirtas, "Introduction," in Glenn A. Kent, *Thinking About America's Defense: An Analytical Memoir* (Santa Monica, CA: RAND Corporation, 2008), 17–18, https://www.rand.org/pubs/occasional_papers/OP223.html; and David A. Ochmanek and Michael Sulmeyer, eds., *Challenges in U.S. National Security Policy: A Festschrift Honoring Edward L. (Ted) Warner* (Santa Monica, CA: RAND Corporation, 2014), 29–39, 74–75, 188, https://www.rand.org/pubs/corporate_pubs/CP765.html.

78 Among many noteworthy examples, see Albert Wohlstetter, Fred Hoffman, R. J. Lutz, and Henry S. Rowen, *Selection and Use of Strategic Air Bases* (Santa Monica, CA: RAND Corporation, 1954), https://www.rand.org/pubs/reports/R0266.html; Barry R. Posen, "Measuring the European Conventional Balance: Coping with Complexity in Threat Assessment," *International Security* 9, no. 3, Winter 1984–1985, 47–88; Christopher J. Bowie et al., *The New Calculus: Analyzing Airpower's Changing Role in Joint Theater Campaigns* (Santa Monica, CA: RAND Corporation, 1993), https://www.rand.org/pubs/monograph_reports/MR149.html; Michael O'Hanlon, "Why China Cannot Conquer Taiwan," *International Security* 25, no. 2, Fall 2000, 51–86; David A. Deptula, *Effects-Based Operations: Change in the Nature of Warfare* (Arlington, VA: Aerospace Education Foundation, 2001), https://secure.afa.org/Mitchell/reports/0901ebo.pdf; and William J. Farrell III and Dean Wilkening, "Modeling Kill Chains Probabilistically," *Military Operations Research Journal* 25, no. 3, 2020, 5–21.

79 Rachel Tecott and Andrew Halterman, "The Case for Campaign Analysis: A Method for Studying Military Operations," *International Security* 45, no. 4, Spring 2021, 63; and Kim R. Holmes, "Measuring the Conventional Balance in Europe," *International Security* 12, no. 4, Spring 1988, 166.

have much to learn from a Pentagon staff officer enduring the drudgery of pleading for requirements to be resourced. Unfortunately, neither the scholar nor the officer has much professional incentive to try to access each other's expertise. By interweaving ideas from disparate communities like these, the E2EPC framework can help researchers gain a foothold in unfamiliar literature as they explore the conditions under which militaries field new capabilities.

Second, the E2EPC framework incorporates a wider range of factors than a typical government program evaluation by, for instance, DoD's Cost Assessment and Program Evaluation office or the Government Accountability Office. These organizations tend to focus more narrowly on cost, schedule, technological maturity, and operational performance. Narrower evaluations of this type are critical and appropriate for organizations whose mandates constrain what and how they research. However, such evaluations often ignore entire domains of human knowledge about politics, organizational behavior, and military history. The E2EPC framework more readily absorbs ideas from these fields, offering a more holistic way to judge progress.

To be clear, the E2EPC framework is not better than narrower evaluations. It has its own drawbacks. Most notably, wider evaluation confronts the challenge of adjudicating evidence taking different forms. In an ideal world, analysts would conduct both narrower and wider evaluations to minimize the risk of missing something important. In real-world Pentagon practice, however, narrower evaluations tend to dominate. By offering an alternative to the dominant approach, the E2EPC framework advances CSBA's long-running work on developing innovative methods of capability assessment.[80]

80 Recent examples include Travis Sharp and Tyler Hacker, *Evaluate Like We Operate: Why the Department of Defense Should Evaluate Weapons Systems as Networked Force Packages, Not Individual Platforms* (Washington, DC: Center for Strategic and Budgetary Assessments [CSBA], August 2023), https://csbaonline.org/research/publications/evaluate-like-we-operate-why-dod-should-evaluate-weapons-systems-as-networked-force-packages-not-individual-platforms; and Tim Sadov and Travis Sharp, "A Prize-Dependent Loitering Time Approach to UAS Routing: Application to South China Sea Maritime Domain Awareness," *Journal of Defense Modeling and Simulation*, February 2025, https://doi.org/10.1177/15485129241312711.

CHAPTER 3

Assessment of the CCA Program

This chapter applies the end-to-end process cycle framework to assess the CCA program's progress to date, presenting the findings as a stoplight chart. The chapter uses six major sources of evidence:

- publicly available information, including Air Force budget data, media reports, government documents, research reports, and event transcripts;
- briefings from Air Force officials;
- confidential interviews and communication by the author with over 30 industry experts from both traditional and nontraditional defense companies;
- a confidential survey of 38 experts from DoD, industry, and think tanks gauging their expectations about affordable mass systems;
- a historical case study on the AQM-34 Lightning Bug, a Vietnam War-era UAS cited by the Air Force as an instructive analogy when it solicited proposals for low-cost UAS designs that fed into the CCA program;[81] and
- an analysis by the author of CCA employment, basing, and sortie generation in a Taiwan scenario, published as a companion volume titled *No Dominant Strategy for Air Dominance*.[82]

81 Joseph Ross, "The AQM-34 Lightning Bug's Lessons for the Collaborative Combat Aircraft," CSBA working paper, December 2023; and AFRL, *Low Cost Attritable Strike Statement of Objectives*, Notice ID AFRL-RQKP-2015-0004, September 10, 2015, 2, https://sam.gov/opp/14b63e83b3345e3bc8fdc5d02d288f62/view.

82 Travis Sharp, *No Dominant Strategy for Air Dominance: Collaborative Combat Aircraft Employment, Basing, and Sortie Generation in a Taiwan Scenario* (Washington, DC: CSBA, May 2025).

With its original framework and wide-ranging interdisciplinary evidence, the chapter scrutinizes the CCA program in ways that no unclassified study has before.[83]

The chapter finds that the CCA program has made significant progress on defining the problem and generating resources, but it has fared less well on the develop, deploy, and employ steps (see Figure 4). This finding could be viewed optimistically or pessimistically depending on one's perspective. The author argues for the optimistic view in this chapter's conclusion.

FIGURE 4: CCA PROGRAM STOPLIGHT CHART SUMMARY

Source: CSBA analysis.

83 Mark A. Gunzinger with Lawrence A. Stutzriem and Bill Sweetman, *The Need for Collaborative Combat Aircraft for Disruptive Air Warfare* (Arlington, VA: Mitchell Institute, February 2024), https://mitchellaerospacepower.org/the-need-for-collaborativecombat-aircraft-for-disruptive-air-warfare; Gregory C. Allen and Isaac Goldston, *Updating Augustine's Law: Fighter Aircraft Cost Growth in the Age of AI and Autonomy* (Washington, DC: CSIS, December 19, 2024), https://www.csis.org/analysis/updating-augustines-law-fighter-aircraft-cost-growth-age-ai-and-autonomy; Benjamin Jensen et al., *Cockpit or Command Center? C2 Options for Collaborative Combat Aircraft* (Washington, DC: CSIS, October 2024), https://www.csis.org/analysis/cockpit-or-command-center-c2-options-collaborative-combat-aircraft; Joseph B. Lyons et al., "Is the Pull-Down Effect Overstated? An Examination of Trust Propagation among Fighter Pilots in a High-Fidelity Simulation," *Journal of Cognitive Engineering and Decision Making* 18, no. 2, June 2024, 99–113; Jesse Breau, Keeley Erhardt, and Joshua Reddis, *Collaborative Combat Aircraft Need Data to Train for Combat*, Mitchell Forum, no. 52 (Arlington, VA: Mitchell Institute, April 2023), https://mitchellaerospacepower.org/collaborative-combat-aircraft-need-data-to-train-for-combat/; Heather R. Penney, *Five Imperatives for Developing Collaborative Combat Aircraft for Teaming Operations* (Arlington, VA: Mitchell Institute, October 2022), https://mitchellaerospacepower.org/five-imperatives-for-developing-collaborative-combat-aircraft-for-teaming-operations/; Bradley Perrett, "Loyal Wingmen Could Be Used to Break Open Enemy Defences," *The Strategist*, Australian Strategic Policy Institute (ASPI), December 16, 2021, https://www.aspistrategist.org.au/loyal-wingmen-could-be-used-to-break-open-enemy-defences/; Bradley Perrett, "Loyal Wingmen Could Be the Last Aircraft Standing in a Future Conflict," *The Strategist*, ASPI, November 22, 2021, https://www.aspistrategist.org.au/loyal-wingmen-could-be-the-last-aircraft-standing-in-a-future-conflict/; and Mark A. Gunzinger and Lukas Autenried, *Understanding the Promise of Skyborg and Low-Cost Attritable Unmanned Aerial Vehicles* (Arlington, VA: Mitchell Institute, October 2020), https://mitchellaerospacepower.org/understanding-the-promise-of-skyborg-and-low-cost-attritable-unmanned-aerial-vehicles/.

Evidence Handling and Assessment Limitations

The author used the evidence collected to rate the CCA program's progress on each step. The ratings depended on the author's judgment and priors. Readers should treat the findings as an informed interpretation. Each step's writeup presents an argument to support the associated rating. Other researchers reviewing the same evidence might reach different conclusions, a common occurrence in policy analysis (including with quantitative data). To provide transparency, the references indicate where information originated.

For the author's communication with defense industry experts, the references note whether the subject worked at a traditional (e.g., Lockheed Martin) or nontraditional (e.g., Anduril) firm. Otherwise, personal identities are kept confidential. This scheme strikes a balance. On the one hand, it allowed interviewees to be less guarded in their comments, resulting in richer information. On the other hand, it discloses one factor—traditional vs. nontraditional firm—that may have affected perspectives and led to biased findings if not managed carefully. Overall, the author's techniques for handling the interview evidence were informed by his prior methodological work on the topic.[84]

The assessment has at least three limitations. First, it only addresses a handful of the many potential activities in each step, emphasizing the issues the author deemed central. Second, it does not reflect ongoing classified work on the CCA program, though the author did consult experts involved with that work. Depending on how classified efforts are evolving, the CCA program's progress could be better or worse than indicated. Third, the assessment evaluates the trajectory of activities that have not been concluded because the CCA program remains in a relatively early stage. Future outcomes will stray from early trends in some areas. As a result, readers should use the assessment as a guide to asking good questions, not as an ironclad prediction of future outcomes.

Step 1: Define Problem

Assessment: Significant progress

Rationale: Key stakeholders agree with the Air Force that the future manned aircraft fleet will face intolerable quantitative disadvantages against China's A2/AD network. The Air Force has successfully presented the CCA as a promising potential solution to this capacity shortfall. Risks to this progress in defining the problem include senior leader turnover and potential developments in U.S.-China military competition.

The Air Force assesses that its projected manned aircraft fleet will be at a worrying numerical disadvantage against China's dense network of fighters, long-range sensors, modernized

84 Travis Sharp, "Sources Cited Analysis: Balancing Safety and Transparency with Confidential Interview Evidence," CSBA working paper, February 2025.

integrated air defense systems, and sea- and land-based missiles.[85] As Air Force Chief of Staff General David Allvin concluded in early 2025, "America needs more Air Force and it needs it now."[86] Many civilian policymakers and outside experts agree.

In its fiscal year (FY) 2025 report, the Senate Armed Services Committee stated, "The committee is deeply concerned for the future of the air superiority mission in the 2030s and 2040s."[87] In 2024, the National Defense Strategy (NDS) Commission concluded, "Given the future demands, the Air Force requires significantly more resources to expand both its capacity and its capabilities."[88] In wargaming a Taiwan conflict, the Center for Strategic and International Studies reported that Chinese attacks against airbases left the United States and Japan with "insufficient aircraft to conduct both air superiority operations and strikes simultaneously."[89]

As these examples show, important stakeholders concur with the Air Force about its manned aircraft capacity shortfall. The Air Force did not create this perception. The idea that the Chinese military could use superior numbers to challenge American forces has existed for over 25 years and was developed outside the Air Force.[90] The point is that non-Air Force policymakers agree with the Air Force's definition of the problem. That agreement provides a strong foundation for the CCA program.

Armed with agreement about the problem, the Air Force has persuaded internal and external audiences of the CCA's promise as a solution. Leaders campaigned for CCAs in 2023 and 2024, with Kendall and top uniformed leaders advocating for the program.[91] Leaders argued the CCA fleet's moderate cost and sizable inventory, a combination dubbed "afford-

85 John A. Tirpak, "Betting on Unmanned Bomber, Fighter 'Families,'" *Air & Space Forces Magazine*, March 23, 2022, https://www.airandspaceforces.com/article/betting-on-unmanned-bomber-fighter-families/; and DoD, *Military and Security Developments Involving the People's Republic of China*, December 2024, 44–73, https://media.defense.gov/2024/Dec/18/2003615520/-1/-1/0/military-and-security-developments-involving-the-peoples-republic-of-china-2024.pdf.

86 David W. Allvin, "It's Make or Break Time: America Needs More Air Force," *Breaking Defense*, January 17, 2025, https://breakingdefense.com/2025/01/allvin-its-make-or-break-time-america-needs-more-air-force/.

87 S. Rep. No. 118-188, *National Defense Authorization Act, 2025*, July 8, 2024, 229, https://www.congress.gov/congressional-report/118th-congress/senate-report/188/1?outputFormat=pdf.

88 National Defense Strategy (NDS) Commission Final Report, July 2024, 41, https://www.rand.org/nsrd/projects/NDS-commission.html.

89 Mark F. Cancian, Matthew Cancian, and Eric Heginbotham, *The First Battle of the Next War: Wargaming a Chinese Invasion of Taiwan* (Washington, DC: CSIS, January 2023), 114, https://csis-website-prod.s3.amazonaws.com/s3fs-public/publication/230109_Cancian_FirstBattle_NextWar.pdf?VersionId=XlDrfCUHet8OZSOYW_9PWx3xtc0ScGHn.

90 DoD, *Quadrennial Defense Review Report*, September 30, 2001, 31, https://history.defense.gov/Portals/70/Documents/quadrennial/QDR2001.pdf?ver=AFts7axkH2zWUHncRd8yUg%3D%3D; and Thomas J. Christensen, "Posing Problems without Catching Up: China's Rise and Challenges for U.S. Security Policy," *International Security* 25, no. 4, Spring 2001, 5–40.

91 John A. Tirpak, "Air Force Touts Unity of Effort in Push Toward New Collaborative Combat Aircraft," *Air & Space Forces Magazine*, November 17, 2022, https://www.airandspaceforces.com/air-force-touts-unity-of-effort-in-push-toward-new-ccas-collaborative-combat-aircraft/; and Eric Lipton, "A.I. Brings the Robot Wingman to Aerial Combat," *New York Times*, September 4, 2023, https://www.nytimes.com/2023/08/27/us/politics/ai-air-force.html.

able mass," would increase U.S. military effectiveness in a war with China, specifically by improving manned aircraft performance.[92] When teamed with CCAs, manned aircraft would suffer fewer losses and achieve more kills against Chinese air threats, according to service officials.[93]

Air Force campaigning for CCAs has borne fruit with key constituencies. In its FY 2025 authorization report, the House Armed Services Committee remarked that CCAs "demonstrate significant potential as a force multiplier capable of overwhelming anti-access area denial threat capabilities that limit force projection. The committee supports rapid development and testing to begin fielding in the late 2020s."[94] Meanwhile, the National Defense Strategy Commission's 2024 report determined the CCA deserved full support.[95] These endorsements signal institutional support for the CCA idea—even if disagreements remain about how to bring it to life.[96]

Unquestionably, Kendall's forceful leadership propelled the CCA program over the past two years. His departure raises questions about whether new leaders appointed by the Donald Trump administration will support CCAs as forcefully as their predecessors. Early signs are encouraging. Defense Secretary Pete Hegseth reportedly included the CCA in a list of priority investments protected from future budget cuts.[97] Still, many senior appointees have not begun performing their roles. Attitudes and politics could change in the months ahead.

The history of the AQM-34 Lightning Bug UAS illustrates the importance of maintaining support for CCAs within the Air Force. During the 1960s and 1970s, the degree of institutional protection for the AQM-34 directly affected its viability, a finding consistent with intraservice military innovation.[98] In its early years, the AQM-34 prospered under the stewardship of the Air Force's Big Safari program office and Strategic Air Command. The organizations implemented aircraft modifications and tactical refinements that enabled the AQM-34 to make noteworthy contributions during the Vietnam War, particularly with reconnaissance.

92 Trevithick, "'Affordable Mass' Concept."

93 Air & Space Forces Association Warfare Symposium, "Advancements in Collaborative Combat Aircraft CONOPs," March 8, 2023, 2, https://www.afa.org/app/uploads/2023/12/Advancements-in-Collaborative-Combat-Aircraft-CONOPs-Transcript.pdf.

94 H. Rep. No. 118-529, *National Defense Authorization Act, 2025*, May 31, 2024, 32, https://www.congress.gov/congressional-report/118th-congress/house-report/529/1?outputFormat=pdf.

95 NDS Commission Final Report, 42.

96 Tirpak, "Air Force 'Very Opposed.'"

97 Dan Lamothe, Alex Horton, and Hannah Natanson, "Trump Administration Orders Pentagon to Plan for Sweeping Budget Cuts," *Washington Post*, February 19, 2025, https://www.washingtonpost.com/national-security/2025/02/19/trump-pentagon-budget-cuts/.

98 Grissom, "Future of Military Innovation Studies," 913–916.

In its later years, however, the AQM-34 lost momentum as the Air Force shifted drone procurement from Big Safari to its normal acquisition processes and eventually transferred control of the aircraft from Strategic Air Command to Tactical Air Command after the Vietnam War. The latter organization's previous commander had rejected the AQM-34 years earlier by reportedly saying, "When the Air Staff assigns eighteen-inch pilots to this command, I'll reconsider the issue!"[99] The Air Force's receptivity to unmanned aircraft has grown enormously since the 1960s, of course, but senior leaders' personal commitment to the CCA program will still greatly influence whether it succeeds or fails.

Just because CCAs appear promising today does not mean they will perpetually favor the United States in its long-term military competition against China. The American move toward CCAs will stimulate Chinese countermoves. China has long excelled at fielding lower cost, higher inventory systems—the competitive space in which CCAs reside. Shifting the competition to an area where China has performed better presents obvious challenges for the United States.

Two potential Chinese countermoves could undercut the CCA's appeal and perhaps lead Air Force planners to pursue other options to solve the problem of insufficient mass.

First, if China developed targeting technologies or techniques that enabled rapid and reliable target identification, specifically by distinguishing CCAs from manned aircraft at standoff distances, then it might conserve munitions for more valuable manned aircraft and thereby avoid some of the envisioned cost-imposing effects of CCAs. Such a development would force the Air Force to rethink the assumption that CCAs will complicate Chinese targeting by greatly increasing the volume of air targets it faced.[100] In this scenario, CCAs would provide less mass than imagined because China would develop a way to discern higher value aircraft and thus would not honor each air threat equally.

Second, if China politically pressured or operationally sabotaged U.S. allies and partners, then it might degrade the basing and sustainment infrastructure required to operate CCAs. The loss of this infrastructure would undercut the viability of CCAs that depend on traditional runways, potentially leading to a wholesale reevaluation of whether CCAs truly addressed the Air Force's mass problem. In this case, CCAs would generate less mass than hoped for because China would neutralize the physical locations required to use CCAs in combat.

Step 2: Generate Resources

Assessment: Significant to moderate progress

Rationale: The Air Force has dedicated significant budgetary resources to the CCA program. Congress has generally supported the initiative. Future threats to steady

99 R. Cargill Hall, "Reconnaissance Drones: Their First Use in the Cold War," *Air Power History* 61, no. 3, Fall 2014, 23.

100 Insinna, "Coming Soon."

resourcing include CCA costs exceeding expectations and CCAs being sacrificed to afford manned aircraft.

The Air Force and Congress have provided the CCA program with strong budgetary support in its early years. For FY 2024, the Air Force requested $392 million for CCA research, development, test, and evaluation (RDT&E).[101] Congress appropriated the full amount without adjustment.[102] For FY 2025, the Air Force requested $557 million for RDT&E, with plans to increase that funding to $1.7 billion in FY 2027 and $3.1 billion in FY 2029.[103] Legislative markups by both authorizers and appropriators generally supported CCAs.[104] Lawmaker support makes sense given that Congress has added billions of dollars to DoD requests since 2016 for UAS and Air Force aircraft procurement.[105] The CCA program sits squarely in an investment area favored by Congress.

The CCA program's funding profile underscores the strength of the Air Force's institutional commitment to the effort. The CCA's initial five-year funding plan consisted of more money, in real terms, than the plans for several other major Air Force programs that stood at a comparable development stage (Figure 5). In other words, initial CCA development has been relatively well funded even compared to other high-priority Air Force programs in the past 15 years. That said, the CCA funding plan also features larger year-to-year changes than the comparison programs. The sawtooth spending profile may pose challenges. For example, tripling CCA spending from FY 2026 (Year 3) to FY 2027 (Year 4) will require finding those resources within the budget, a task that could prove difficult if total Air Force spending is limited.

101 Air Force, *FY 2024 Budget Estimates, Research, Development, Test & Evaluation,* vol. 2, March 2023, 415, https://www.saffm.hq.af.mil/Portals/84/documents/FY24/Research%20and%20Development%20Test%20and%20Evaluation/FY24%20Air%20Force%20Research%20and%20Development%20Test%20and%20Evaluation%20Vol%20II.pdf?ver=pYOQLrjX71gVe8w6FCJOwg%3d%3d.

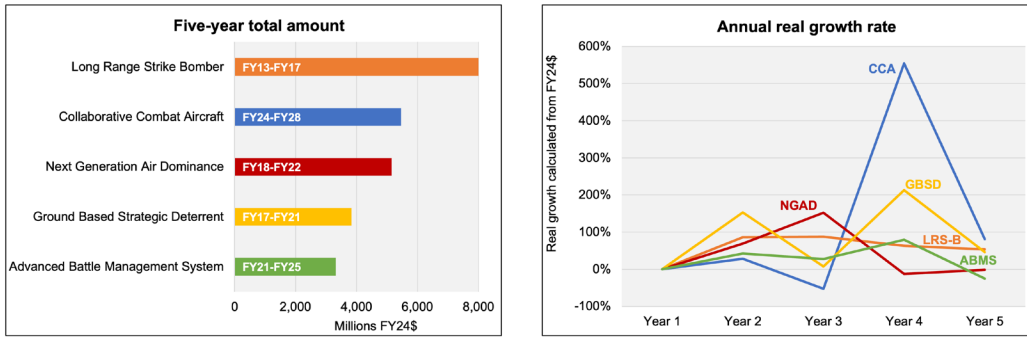
102 H.R. 2882/Pub. L. 118-47, *Further Consolidated Appropriations Act, 2024*, March 23, 2024, 273, https://www.govinfo.gov/content/pkg/CPRT-118HPRT55008/pdf/CPRT-118HPRT55008.pdf.

103 Air Force, *FY 2025 Budget Estimates, Research, Development, Test & Evaluation,* vol. 2, March 2024, 427, https://www.saffm.hq.af.mil/LinkClick.aspx?fileticket=jQCmIF-YLMg%3d&portalid=84.

104 The FY 2025 defense authorization act recommended nearly full funding for NGAD. H.R. 5009/Pub. L. 118-159, *National Defense Authorization Act, 2025*, December 3, 2024, 579, https://www.congress.gov/118/bills/hr5009/BILLS-118hr5009enr.pdf. Meanwhile, House appropriators proposed cutting $26 million and Senate appropriators proposed cutting $70 million from the $557 million FY 2025 request. Despite the cut, the House Appropriations Committee noted it "remains supportive of the effort." H. Rep. No. 118-557, *Department of Defense Appropriations Bill, 2025*, June 17, 2024, 201, 211, https://www.congress.gov/congressional-report/118th-congress/house-report/557/1?outputFormat=pdf; and S. Rep. No. 118-204, *Department of Defense Appropriations Bill, 2025*, August 1, 2024, 229–230, https://www.congress.gov/congressional-report/118th-congress/senate-report/204/1?outputFormat=pdf.

105 Travis Sharp and Casey Nicastro, "Hardwired for Hardware: Congressional Adjustments to the Administration's Defense Budget Requests, 2016 to 2023," *Æther* 3, no. 1, Spring 2024, 10, 13, https://www.airuniversity.af.edu/Portals/10/AEtherJournal/Journals/Volume-3_Number-1/Sharp_Nicastro.pdf.

FIGURE 5: FIVE-YEAR RDT&E FUNDING FOR CCA VS. OTHER HIGH-PRIORITY PROGRAMS



Source: CSBA analysis of Air Force budget documents. Appendix A provides sources.

Notes: FY24$. The analysis used the following Year 1 values: CCA FY24, LRS-B FY13, NGAD FY18, GBSD FY17, and ABMS FY21. These years featured the first robust instantiations of each program's five-year RDT&E spending trajectory, making them a reasonable baseline for comparison.

One factor certain to sap support for CCAs is if its cost were to exceed expectations. The Air Force's central argument for acquiring the aircraft has been obtaining affordable mass. Any significant cost growth would unravel this logic, potentially dooming the entire endeavor. The CCA's software development, software sustainment, and logistics tail are areas where future costs might be higher than observers expect.[106] These costs could top preliminary estimates not because of mismanagement but rather because they are not yet fully understood.

Autonomy systems illustrate this point. A large, well-funded development effort is required to support the mission autonomy underpinning the CCA. The Air Force wants this autonomy to flow into other programs, meaning the effort extends beyond the CCA program. The questions then become: How much will this autonomy effort cost, including for sustainment? How much of that cost should be attributed to the CCA? Clear answers do not yet exist, but asking the questions highlights the problem with conceptualizing CCA costs strictly as procurement price per airframe.

Once again, the Lightning Bug serves as a cautionary tale. Operating the AQM-34 incurred numerous unexpected costs, from developing an expensive midair retrieval system to flying manned escort and support aircraft in support of its missions. Although some AQM-34 variants stayed on budget and on schedule, many experienced cost overruns and schedule slips.[107] The unbridled enthusiasm exhibited by advocates of the aircraft likely contributed to these problems by fostering unrealistic expectations about what it could achieve. The current excitement surrounding the CCA program presents the analogous risk that the wave of exuberant

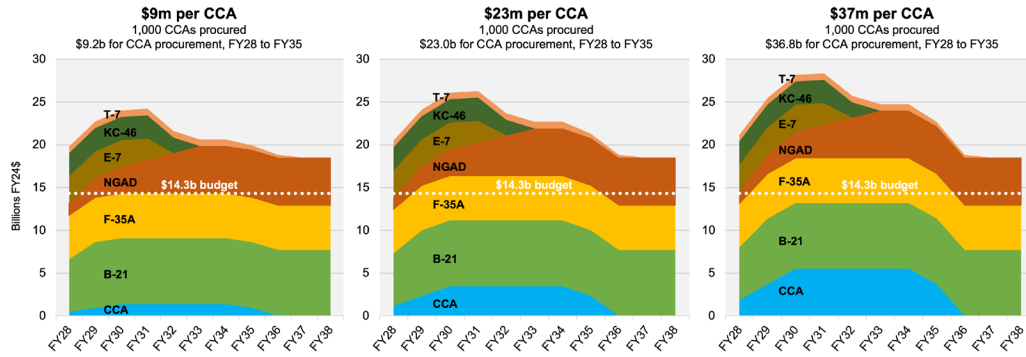
106 Author's communication with industry expert from traditional defense firm, July 27, 2023; author's discussion with industry experts from nontraditional defense firm, June 27, 2023; and author's communication with industry expert from traditional defense firm, August 27, 2024.

107 William E. Krebs, *Did We Err in the Development of Remotely Piloted Vehicles (RPVs)?,* Rep. No. MS018-79 (Maxwell, AL: Air War College, April 1979), 17, https://aul.primo.exlibrisgroup.com/discovery/delivery/01AUL_INST:AUL/1281074240006836.

hopes will crash on the shoals of operational reality, making it imperative that CCA developers stay within the Air Force's cost targets while meeting critical technology benchmarks.

Increases in CCA costs would put additional pressure on plans to procure expensive manned aircraft. If push came to shove, the Air Force and Congress might sacrifice CCAs to save manned aircraft. In FY 2028, when CCA production is intended to begin, the Air Force will be procuring several classes of new aircraft. The cost of those new aircraft likely will surpass the resources available if future budgets resemble recent trends (Figure 6). Air Force leaders have acknowledged the likely unaffordability of current plans.[108]

FIGURE 6: AIRCRAFT PROCUREMENT SPENDING UNDER DIFFERENT CCA COSTS, FY28 TO FY38



Source: CSBA analysis of Air Force budget documents and other publicly available information. Appendix A provides sources and assumptions.

Notes: FY24$. Analysis assumes 1,000 CCA fleet. New aircraft procurement budget set at $14.3b based on FY25 request with some assumed growth prior to FY28. CCA unit cost values selected to represent range emphasized in public discussions.

Air Force aircraft procurement faces the familiar bow wave situation in which anticipated costs surpass projected spending. The bow wave will prove very challenging even if the CCA's cost per aircraft falls at or under the preliminary cost target ($20 million to $30 million). If the CCA's cost grew above that target, it would consume so many resources that the Air Force probably would not have enough money remaining for planned purchases of manned aircraft.

The Air Force could reduce annual CCA purchases to hold costs down, but doing so would result in the per-aircraft price decreasing less than it would under the optimal production rate. Given the CCA program's early stage and lack of an entrenched advocacy network, the Air Force likely could reprogram the CCA's future funding to other priorities without provoking bruising political fights with Capitol Hill.

Even if the Air Force prioritized procuring CCAs over manned aircraft, rebuking its pilot culture, the tradeoff would have a limit. The Air Force's operating concept is for CCAs to be

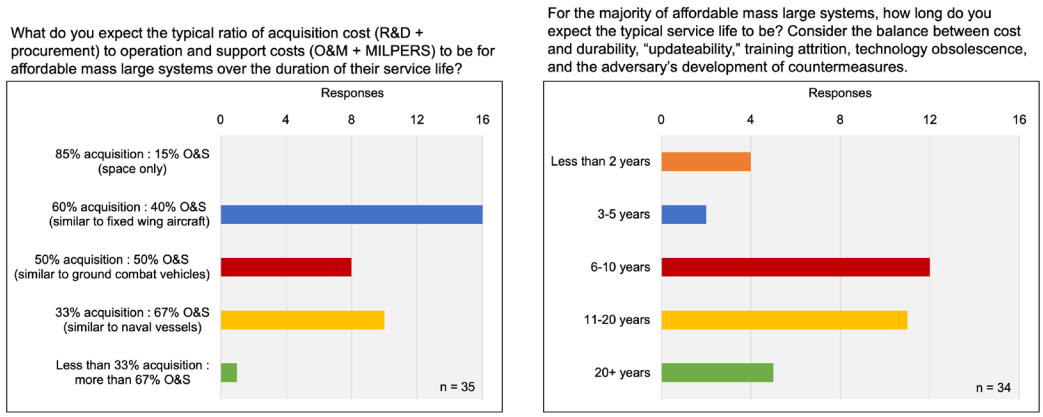
108 Losey, "Next-Gen Stealth Tanker."

loyal wingmen to manned aircraft. CCAs are therefore tethered to manned aircraft both operationally and budgetarily. Political opposition would likely grow if the loyal wingman started receiving outsized funding inconsistent with its supporting role vis-à-vis its manned aircraft master. The Air Force's recent pause of the NGAD manned fighter program led insiders to worry the service and Congress might delay CCAs as well.[109] Their anxiety illustrated the perceived link between CCA funding and manned aircraft funding. What happens to one affects the other.

CCA procurement costs are not the only budget pinch. The Air Force also must fund the aircraft's operation and support (O&S) costs, which include the personnel, supplies, and equipment required throughout its service life. To the author's knowledge, the Air Force has not released details about expected CCA O&S costs. Industry experts also have struggled to obtain information on this topic.[110]

To overcome this knowledge gap, CSBA administered a confidential survey in January 2025 to gauge insiders' expectations about large affordable mass systems such as CCAs. Figure 7 shows the results for two O&S-related questions. Respondents disagreed about basic matters of program planning, a sign that even experts remain unsure how things will unfold. Respondents generally believed the ratio of acquisition cost to O&S cost would fall in the 60:40 to 33:67 range, with a plurality choosing the 60:40 option that mirrors fixed-wing aircraft. Meanwhile, most respondents viewed a service life of six to ten or 11–20 years as most likely, with ten years approximating the central tendency.

FIGURE 7: CSBA SURVEY RESULTS FOR COST RATIO AND SERVICE LIFE



Source: CSBA confidential survey of 38 experts from DoD, industry, and think tanks, conducted January 14 and 16, 2025. Illustrative systems for cost ratios (i.e., space, fixed wing aircraft, etc.) taken from Gary Jones, Edward White, Erin T. Ryan, and Jonathan D. Ritschel, "Investigation into the Ratio of Operating and Support Costs to Life-Cycle Costs for DoD Weapon Systems," *Defense Acquisition Research Journal* 21, no. 1, January 2014, 449, https://apps.dtic.mil/sti/citations/ADA600495.

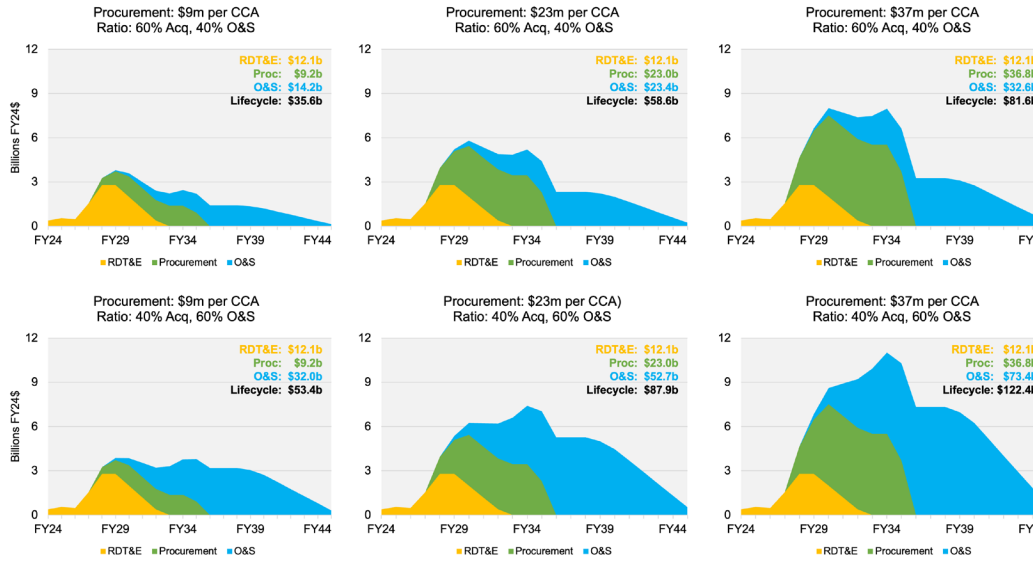
109 Steve Trimble, "U.S. Airpower Debate Opened by NGAD Hiatus Nears Resolution," *Aviation Week*, February 12, 2025, https://aviationweek.com/defense/budget-policy-operations/us-airpower-debate-opened-ngad-hiatus-nears-resolution.

110 Author's communication with industry expert from traditional defense firm, July 27, 2023.

Notes: Respondents were visually prompted to think of current CCA offerings as large systems. Paper survey of six questions administered to two unique groups on January 14 and 16. Six versions of the survey were distributed to vary question ordering. The survey kept each respondent confidential but asked four questions about professional background. Figures exclude missing and invalid responses.

One can use the survey, procurement estimate, and RDT&E plan to model the CCA program's total lifecycle cost—a cost the Air Force will have to squeeze into its budget alongside its other priorities. Figure 8 reports six lifecycle cost scenarios. The scenarios vary CCA procurement unit cost ($9 million, $23 million, $37 million) and lifecycle cost ratio (60:40, 40:60) while holding constant RDT&E spending, CCA fleet size, and service life. The fleet size and unit cost follow the procurement estimate. The service life and cost ratio reflect the survey, with 40:60 used in place of 33:67 to reflect the distribution of responses. Figure 9 depicts the six scenarios in terms of total annual costs (RDT&E, procurement, and O&S) to accentuate the annual demand imposed on the Air Force budget.

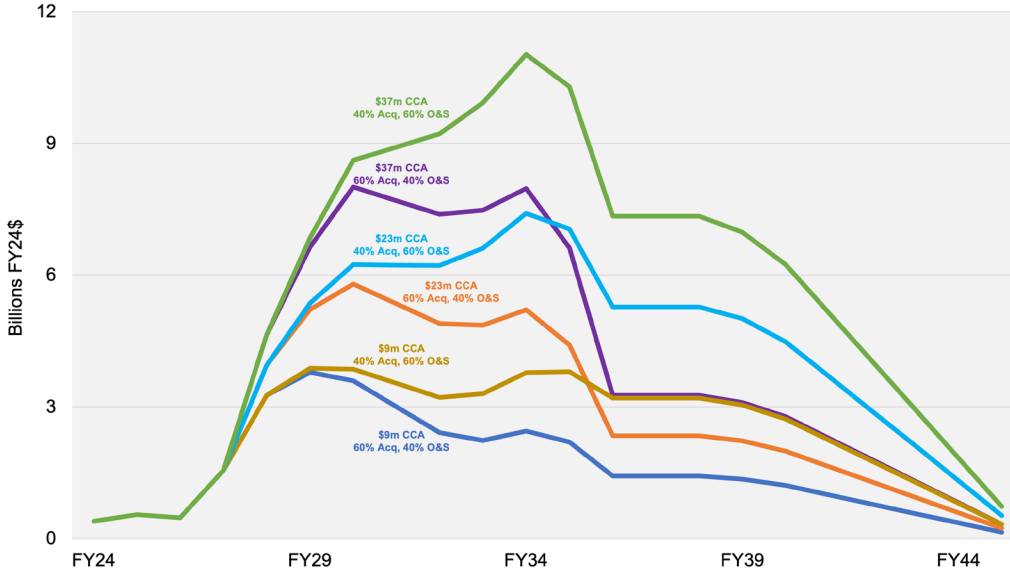
FIGURE 8: CCA LIFECYCLE COSTS IN SIX SCENARIOS, FY24 TO FY45



Source: CSBA analysis of data presented in Figures 5, 6, and 7.

Notes: FY24$. Analysis assumes 1,000 CCA fleet and ten-year service life. CCA unit cost values selected to represent range emphasized in public discussions. Analysis assumes aircraft enter active inventory in the fiscal year following procurement and operate for full ten-year service life, meaning training and combat losses are excluded. RDT&E reflects FY24 enacted, FY25 requested, FY26–FY29 projected, and CSBA-assumed FY30–FY32 ramp down to the FY24 level from which program started.

FIGURE 9: CCA ANNUAL COST (RDT&E + PROCUREMENT + O&S) IN SIX SCENARIOS, FY24 TO FY45

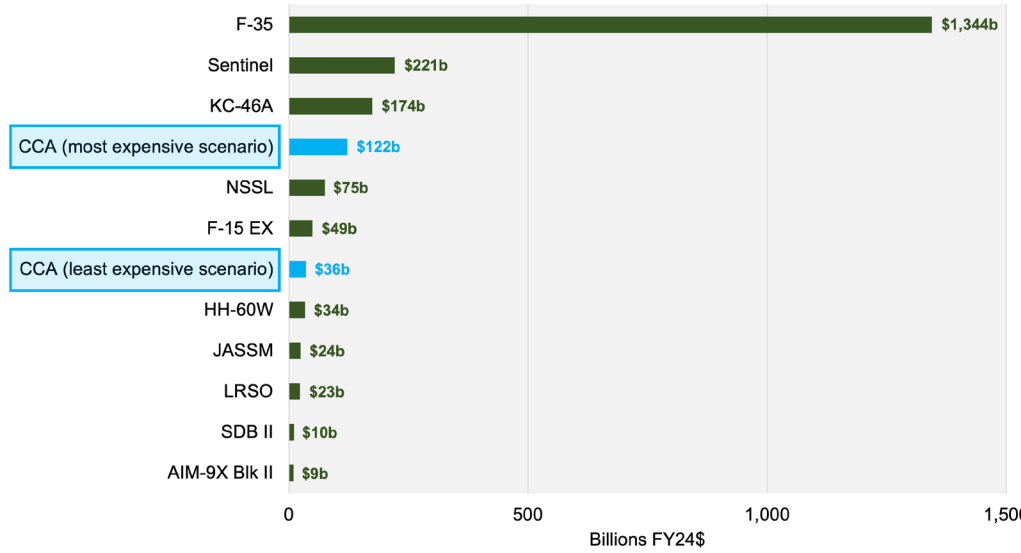


Source: CSBA analysis of data presented in Figures 5, 6, and 7.

Notes: FY24$. See Figure 8.

The results highlight a reality that all defense professionals understand but popular commentary often ignores: A weapon's procurement unit cost offers an astonishingly incomplete picture of the total resources required to field that weapon. Under the assumptions used here, even the least expensive CCA ($9 million) would have total lifecycle costs in the $35 billion to $55 billion range. Compared to a sample of other weapons systems relevant to Air Force planners, the least expensive CCA lifecycle cost scenario ranks in the middle of the pack (Figure 10). The most expensive CCA scenario ranks closer to the top, though it still represents a mere fraction (9 percent) of F-35 costs across DoD for all variants.

FIGURE 10: CCA LIFECYCLE COSTS VS. OTHER WEAPONS SYSTEMS



Source: Data from Figure 8 and CSBA analysis of DoD's December 2023 selected acquisition reports. Appendix A provides sources.

Notes: FY24$. F-35 includes all variants engine and aircraft. Lifecycle cost includes acquisition, O&S, and disposal. Comparison weapons systems selected to represent the range of lifecycle costs in the current procurement portfolio.

Overall, the analysis suggests the CCA's affordability is a matter of perspective. Its total lifecycle costs may be far greater than popularly imagined but far less than the costliest weapons systems. Whether the Air Force will continue successfully generating resources for the CCA will depend on how well it explains the aircraft's value relative to cost, particularly to Congress.

Step 3: Develop Capability

Assessment: Moderate to limited progress

Rationale: The Air Force has rapidly advanced CCA capability. Congress has applauded its performance. Despite this progress, the Air Force has hesitated to narrow down future combat roles, instead stressing the CCA's usefulness across many missions. This emphasis obscures the need to make tradeoffs. Clinging to too many missions interferes with the detailed work needed to make progress on other steps of the end-to-end process cycle.

The CCA program begins with a blanker slate than the standard acquisition scenario, in which developers design a replacement for an existing system. They use the antecedent system's operational employment and organizational structure as a starting point for crafting the successor system. With a new manned bomber, for example, developers might begin by assuming the new aircraft will perform existing missions, belong to existing units, and fly with pilots trained in existing schools.

This standard approach is not helpful for the CCA. It is not replacing an existing system that can serve as a dominant antecedent to anchor planning.[111] As a result, the Air Force must answer first-order questions about the aircraft's missions, design, program structure, sustainment, and much else.

Given this daunting situation, the Air Force deserves great credit for its concrete and rapid progress with developing the CCA. In only 24 months, it narrowed the pool of vendor offerings for the first increment of airframes and assessed needs for the second increment.[112] It leveraged available acquisition authorities to avoid vendor lock and ensure rapid iteration of the mission autonomy system. It also activated an experimental operations unit to test concepts for deployment and employment. This flurry of activity in no way guarantees success, but as with defining the problem (Step 1) and resourcing (Step 2), it shows that the CCA program is positioned for potential success because the Air Force has done many things right.

Congress has applauded the Air Force's progress with developing CCAs. As the House Appropriations Committee's FY 2025 report noted, the committee "is pleased that CCA Increment 1 downselected after only two years, having demonstrated early and successful collaboration between operators, technologists, acquirers, and industry."[113] Legislative goodwill like this remains indispensable to the CCA's long-term prospects.

Despite these achievements, the Air Force has hesitated to specify exactly what roles the CCA would perform in future combat.[114] This lack of specificity is a big problem for capability development because missions drive aircraft design, fleet size, and logistics structure. If planners treat employment generically, then everything that follows must also be treated generically, resulting in less progress throughout the end-to-end process cycle. This is exactly what has happened with the CCA program.

In public and private, Air Force leaders have tended to stress the CCA's broad usefulness "across diverse missions," as U.S. Pacific Air Forces put it, while downplaying the fact that tradeoffs must be made to excel at any given mission.[115] Exemplifying this tendency, Lieutenant General Dale White, a top Air Force acquisition official, once said about CCA capability development: "We could not force decisions in design that limited the flexibility of the war fighter or the commander…to make that decision at the beginning of any and each

111 That said, numerous manned and unmanned weapons systems offer valuable lessons for the CCA, as demonstrated by the chapter's comparisons to the AQM-34 Lightning Bug.

112 This paragraph draws on Air Force, "Collaborative Combat Aircraft (CCA) Overview," briefing provided to CSBA, 2024, 4–5.

113 H. Rep. No. 118-557, 211.

114 Steve Trimble, "Lockheed CEO Revives CCA Debate over Combat Readiness Timing," *Aviation Week*, October 22, 2024, https://aviationweek.com/defense/aircraft-propulsion/lockheed-ceo-revives-cca-debate-over-combat-readiness-timing.

115 Air Force, *PACAF Strategy 2023: Evolving Airpower*, September 2023, 9, https://www.af.mil/Portals/1/documents/2023SAF/PACAF_Strategy_2030.pdf; and Tirpak, "Brown: Collaborative."

mission."[116] Although flexibility is desirable, today's force planners must make choices that tie the hands of future service members in one way or another. In the real world of resource constraints and opportunity costs, it is impossible to keep all options on the table.

The Lightning Bug demonstrates the difficulties that can arise when grasping for more missions rather than focusing on what a system can do best. As the AQM-34 settled into its niche mission of photoreconnaissance, Ryan Aeronautical and the Air Force experimented with aircraft modifications and new employment concepts. These concepts included using AQM-34s with dummy payloads as decoys to confuse enemy radar, employing AQM-34s to perform anti-air and anti-ship strikes in support of Navy fleet operations, and testing the armed BGM-34 variant to strike targets alongside fighters and bombers during surface-to-air missile suppression operations.[117]

Although these concepts were innovative, the AQM-34 still had room to improve its primary specialty, photoreconnaissance. According to an authoritative estimate, persistent challenges with its navigation system caused it to veer off course and miss its planned reconnaissance targets more than half the time.[118] The state of technology at the time surely contributed to these routing errors. Yet, perhaps they could have improved if developers had concentrated on enhancing the AQM-34's photo-reconnaissance performance rather than diverting their attention to new employment concepts. For CCA developers, the lesson is that there is a tradeoff between pursuing new missions and improving primary missions. An organization should understand these tradeoffs before deciding how to proceed.

One factor that could pull the CCA program even further from the needed specificity about missions would be if decision makers started prioritizing threats other than China. CCAs likely would prove valuable in combat against Russia, Iran, or North Korea. However, war with China places unique demands on CCAs due to the Western Pacific's vast distances and limited landmasses as well as China's formidable military capabilities.

Although considering multiple contingencies often improves force planning, the risk with CCAs is that broader planning will trigger aircraft design tradeoffs that increase multi-scenario performance but decrease China-specific performance.[119] Air Force leaders have recognized the risk of CCA mission creep, but policymakers in the Office of the Secretary of Defense, White House, and Congress also shape the program's direction. They may push for broader CCA missions based on their organizational priorities.[120]

116 Air & Space Forces Association Warfare Symposium, "Advancements in Collaborative Combat Aircraft CONOPs," 2.

117 William Wagner, *Lightning Bugs and Other Reconnaissance Drones* (Fallbrook, CA: Armed Forces Journal International, 1982), 110–111, 157–161, 170–179, 182–183.

118 Ehrhard, *Air Force UAVs*, 24.

119 Author's discussion with industry experts from traditional defense firm, May 11, 2023.

120 Laura Heckmann, "Collaborative Combat Aircraft Will Be 'in a Lot of Places,' Air Force General Says," *National Defense*, September 11, 2023, https://www.nationaldefensemagazine.org/articles/2023/9/11/aircraft-will-be-in-a-lot-of-places-air-force-official-says/.

Step 4: Prepare Organizations

Assessment: Moderate progress

Rationale: The Air Force has worked steadily to build confidence in mission autonomy, a necessary condition for integrating CCAs into the force. Yet, there remain organizational obstacles to overcoming the unprecedented challenge of fielding highly capable autonomous systems. These obstacles include classification barriers to industry entry and operator skepticism.

The Air Force has not yet achieved the confidence in mission autonomy that is necessary for the CCA program's success, but it has instilled greater confidence. Continued progress in this area will prove essential to CCAs joining the force.

Building confidence in mission autonomy will require that (a) technology performs as desired and (b) users believe technology will perform as desired. These two factors are related but not the same thing. Humans often fail to update beliefs about the future that are based on past outcomes.[121] Understanding this limitation of human perception will prove important to the CCA program's success. The Air Force must not only field new technology that performs well but also inculcate the appropriate beliefs about that technology among personnel. The goal is balance, with users viewing mission autonomy as neither omnipotent nor ineffectual but rather as a tool capable of producing results under the right conditions. The evolution in attitudes toward UAS over 20 years of fighting in Afghanistan and Iraq demonstrates that skepticism can give way to trust.[122] This evolution will need to happen faster with CCAs.

The CCA program has two advantages as it works to increase confidence in mission autonomy. First, it has not started from scratch and does not have to generate all the required confidence on its own. CCAs leverage years of development conducted through the Air Force's Skyborg initiative, the Defense Advanced Research Projects Agency's Air Combat Evolution, and other efforts.[123] According to industry experts, these initiatives are only part of the effort and investment ultimately needed to field viable solutions.[124] Nevertheless, the CCA program enjoys the benefit of building on prior work.

Second, Air Force leaders have consistently stated that fielding CCA-caliber autonomy is difficult but achievable. As Major General Jobe once noted, "We did not swing for the fences. We went for a base hit. I'm not talking about 'Terminator'…autonomy. We're talking about

121 Alexander Coutts, "Good News and Bad News Are Still News: Experimental Evidence on Belief Updating," *Experimental Economics* 22, 2019, 369–395.

122 Richard Whittle, "Predator Started Drone Revolution, and Made Military Innovation Cool," *Breaking Defense*, March 9, 2018, https://breakingdefense.com/2018/03/predator-started-drone-revolution-and-made-military-innovation-cool/.

123 Allen and Goldston, *The Department of Defense's Collaborative Combat Aircraft Program*, 4.

124 Author's communication with industry expert from traditional defense firm, August 9, 2024.

real things and real behaviors that real aircraft can do, and this is entirely an art of the possible."[125] Honesty about challenges should inspire greater confidence in a U.S. military culturally predisposed to prefer frank communication from senior leaders.

Despite these advantages, barriers remain to the requisite confidence in mission autonomy. One obstacle is the security classification barriers associated with system development. These barriers can inhibit industry, particularly smaller technology companies, from joining experimentation efforts. Nontraditional firms have reported that the bespoke security setups created for each initiative sometimes prevent them from participating.[126] Wrangling over access to government customers is expected as firms compete for lucrative contracts. That said, the CCA program's novelty and ambition suggest a need to err on the side of inclusivity with industry.

A second obstacle is operator skepticism about the effectiveness of autonomy systems. To date, pilots involved with development have delivered mixed reviews. On the negative side, as one pilot remarked early in the CCA program: "Sure, we've seen some great tech demos, but as a real capability that I could go to war with, they're not much farther along than PowerPoint."[127] On the positive side, more recent demonstrations have received better responses, with pilots reporting that controlling simulated CCAs was easier than expected and quickly learnable.[128]

On the one hand, pilot skepticism may fade with time, especially as technology improves and artificial intelligence becomes more common in daily life. On the other hand, many pilots will continue questioning whether mission autonomy helps or hinders them in combat.

Operator skepticism stems from a recurring concern about new technology. Warfighters want operational needs to drive technological development, not the other way around.[129] They resist simplifying operational realities to prop up favored technologies. If CCA autonomy experiments trivialize threats, artificialize sustainment, minimize tactics, or summarize success using any variable other than operational effectiveness, then pilots will dismiss the results—and rightfully so. Ultimately, operators want to be shown how CCAs will enable the Air Force, which is and always will be led by people not machines, to accomplish its missions.

The path to overcoming skepticism is easy to identify if hard to tread. Pilots must continue participating actively in technology development. As former F-16 pilot Heather Penney remarked, "Without an understanding of how CCA think, how they make decisions, and

125 Air Force, "Background Briefing."

126 Author's discussion with industry experts from nontraditional defense firm, June 27, 2023.

127 Quoted in Penney, *Five Imperatives*, 4.

128 Author's communication with industry expert from traditional defense firm, August 20, 2024.

129 Thomas G. Mahnken, *Technology and the American Way of War since 1945* (New York: Columbia University Press, 2008), 219–229.

why they take certain actions, warfighters will be unable to anticipate how their autonomous teammates will react when given inputs and data."[130] Including pilots in developing CCA mission autonomy does not guarantee they will gain confidence in it, but excluding them likely means they never will.

Step 5: Deploy Capability

Assessment: Limited progress

Rationale: The Air Force has released few details about CCA basing and sustainment. Although it must avoid releasing operationally sensitive information, fielding CCAs will place additional demands on operating locations, logistics, and alliance relationships already stressed by supporting U.S. manned aircraft in highly contested environments. Assuaging concerns about basing and sustainment should be a top Air Force priority in the near term.

The CCA program has not yet promulgated basing and sustainment concepts that experts consider convincing.[131] This gap stems in part from the classification of sensitive details and the CCA program's relatively early stage.[132] Still, the lack of clarity, even among knowledgeable insiders, suggests basing and sustainment concepts remain underdeveloped. Even in its own documents, the Air Force damns basing progress with faint praise by listing achievements such as "actively conducting research" about locations "pending site surveys [and] decisions"—hardly the concrete advances evident elsewhere in the program.[133] As noted by Lieutenant Colonel Matthew Jensen, director of the experimental operations unit developing CCA deployment concepts, "We're fighting against cultural inertia."[134]

Recent Air Force doctrine has emphasized the agile combat employment (ACE) concept.[135] ACE calls for dispersing and maneuvering air assets throughout a theater to increase survivability

130 Penney, *Five Imperatives*, 5.

131 Author's discussion with industry experts from traditional defense firm, May 11, 2023; author's communication with industry expert from traditional defense firm, July 27, 2023; and author's communication with industry experts from nontraditional defense firm, June 27, 2023.

132 Heckmann, "Collaborative Combat Aircraft"; and Duke Z. Richardson, David S. Nahom, and Joseph T. Guastella, testimony before the Senate Armed Services Committee, "Air Force Force Structure and Modernization Programs," May 17, 2022, 15, https://www.armed-services.senate.gov/imo/media/doc/SASC-AL%20Written%20Testimony_FINAL%20CLEARED%20(1).pdf.

133 Air Force, "Collaborative Combat Aircraft (CCA) Overview," 4.

134 Heather Penney, Gary Glojek, and Matthew Jensen, "Ready to Fight All Night: High-Tempo Airpower Generation," *Aerospace Advantage* podcast, Mitchell Institute, July 19, 2024, at 43:08, https://mitchellaerospacepower.org/episode-193-high-tempo-airpower-generation/.

135 Air Force, *Agile Combat Employment*, Air Force Doctrine Note 1-21, August 23, 2022, https://www.doctrine.af.mil/Portals/61/documents/AFDN_1-21/AFDN%201-21%20ACE.pdf.

using a hub and spoke network of bases. Executing ACE will mean conducting operations away from main airbases, using more austere locations to complicate adversary targeting.[136]

Air Force leaders envision having CCAs at main bases when a conflict begins and then dispersing them to other locations.[137] As General Kenneth Wilsbach, commander of Air Combat Command, remarked, "Every single additional airfield that I can operate from is… another airfield that China has to put into their targeting…and allocate resources for them, which dilutes their ability to shut us down completely."[138]

Although dispersing CCAs denies China the ability to concentrate offensive fires on main bases, it also affects CCA sortie generation. The impact on sorties defies easy prediction.[139] On the one hand, a main base might enjoy a sortie-generation advantage because it has significant capabilities (including ground personnel) for fuel storage and pumping, munitions handling, and aircraft maintenance.[140] These capabilities would have to be distributed outward in dispersed configurations, increasing the risk of disruption and delayed sorties. As RAND concluded about dispersion, "Regardless of the concept it uses, the Air Force will have to trade efficiency for survivability in a high-end fight."[141] On the other hand, a main base's assumed sortie-generation advantage might disappear as its aircraft inventory (both unmanned and manned) increased. At some point, the number of aircraft would overwhelm ground support capacity. Dispersed configurations might avoid this overloading problem.

The prospect of hundreds and perhaps thousands of CCAs operating alongside manned aircraft would further congest the U.S. Indo-Pacific basing network. That network has struggled with squeezing many forces into few locations. Given this challenge, the Air Force's interest in designing CCAs with reduced runway takeoff capability appears vitally important.[142] Shorter takeoff distances would allow CCAs to use runways or paved surfaces that manned aircraft could not, alleviating pressure on the basing network.

Ideal CCA basing locations depend on how the aircraft are employed. According to *No Dominant Strategy*, for a Taiwan scenario in which a U.S. fleet of 500 CCAs deploys no more than 36 aircraft per base, a set of 14 bases would maximize sorties in vicinity of Taiwan regardless of whether the CCAs conduct "stay on station" persistence or "rapid return" hit and runs (Figure 11). However, those 14 bases would not maximize sorties if the CCAs

136 Sean Carberry, "Forget Hardened Bases, Pacific Conflict Requires Agile Combat Employment, Commander Says," *National Defense Magazine*, March 8, 2023, https://www.nationaldefensemagazine.org/articles/2023/3/8/forget-hardened-bases-pacific-conflict-requires-agile-combat-employment-commander.

137 Trevithick, "Future Air Combat Drone Performance."

138 Heckmann, "Collaborative Combat Aircraft."

139 Sharp, *No Dominant Strategy*, chaps. 1 and 3.

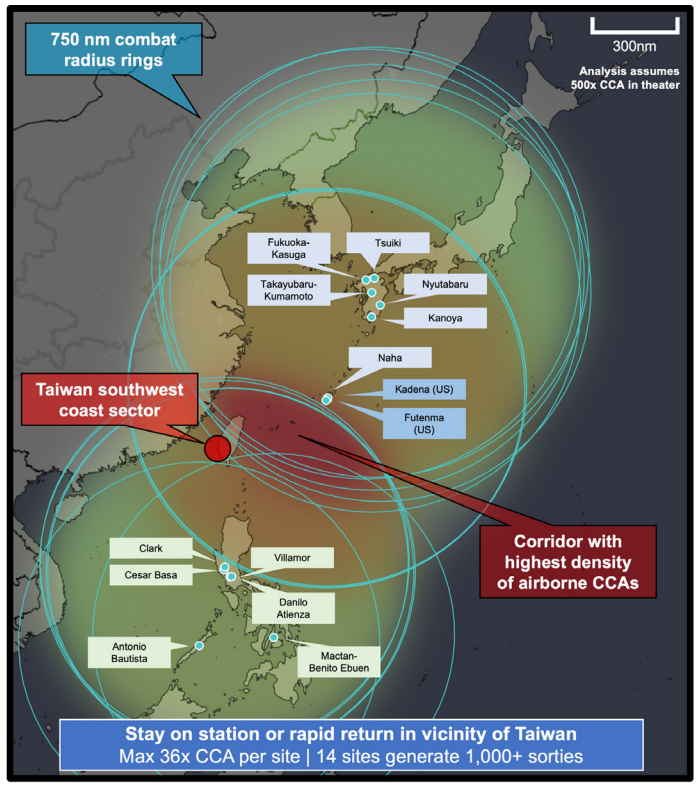
140 Miranda Priebe et al., *Distributed Operations in a Contested Environment: Implications for USAF Force Presentation* (Santa Monica, CA: RAND Corporation, 2019), xi, https://www.rand.org/pubs/research_reports/RR2959.html.

141 Priebe et al., *Distributed Operations*, xi.

142 Air Force Materiel Command, *Future Collaborative Combat Aircraft (CCA) RFI*.

prioritized operating in theaterwide areas beyond Taiwan. Broadening the combat air patrol locations encourages more use of sites like Iwakuni that feature higher sortie throughput due to having more ground support capability and lying further from threat-saturated Taiwan. In sum, the best basing locations depend on whether CCAs swarm the conflict epicenter in Taiwan or fan out to inflict damage on Chinese forces elsewhere.

FIGURE 11: U.S. CCA AIRBORNE DENSITY IN TAIWAN SCENARIO



Source: Sharp, *No Dominant Strategy*, chap. 3.

Notes: Analysis assumes inventory of 500 CCAs in theater and unrefueled combat radius of 750nm. The 14 optimal basing sites are the same for rapid return and stay on station. See Sharp, *No Dominant Strategy*, for details.

If CCAs use runways for takeoff and landing, as the Air Force is planning, then they will compete for space against manned aircraft. Force developers have explored alternatives to unmanned aircraft takeoff and recovery, including rocket-assisted takeoff, land-based electromagnetic aircraft launch systems, and parachute recovery.[143] Each option has its own complications, however, and none aligns with Air Force thinking about CCAs.[144]

143 Leftwich, DeBlois, and Orletsky, *Supporting Combat Power Projection*.

144 Air Force Materiel Command, *Future Collaborative Combat Aircraft (CCA) RFI*; and author's communication with industry expert from traditional defense firm, July 27, 2023.

The Lightning Bug illustrates how alternative launch and recovery methods can impose logistical burdens and unexpected costs. After the aircraft's original recovery method—parachute descent to a ground landing—damaged too many airframes, Ryan, the AQM-34's producer, and the Air Force adopted the midair retrieval system (MARS).[145] When the AQM-34 returned to permissive airspace, a CH-3 helicopter retrieved it midair with a recovery hook. MARS proved highly effective, with the AQM-34's retrieval rate reaching 96.7 percent.[146] Despite MARS's success, it required specialized equipment and crews that increased costs and lift requirements. According to one estimate, MARS represented half of the AQM-34's total operating cost.[147] Another estimate concluded that transporting 36 AQM-34s required nearly as much airlift capacity as transporting 72 F-4 fighter aircraft.[148] Such sustainment burdens help explain the Air Force preference for runway-launchable CCAs.

Although fielding shorter takeoff CCAs might lessen competition for runway space, it would not reduce CCA sustainment requirements. Because the Air Force intends CCAs to be reusable, meaning they will fly sorties until they are destroyed or the conflict ends, they will require sufficient fuel, maintenance, and munitions for continuous flight operations. New CCAs may also be needed to replace those destroyed in battle.

CCA sustainment and reconstitution needs will add to fleetwide manned aircraft needs, increasing total demand on the logistics network.[149] If CCAs with shorter takeoff capability operate from different locations than manned aircraft, then the Air Force must deliver (or preposition) CCA sustainment capacity near those locations. This involves not only stationing matériel but also supporting personnel who use that matériel. Adding a large CCA fleet to the U.S. military's Indo-Pacific forces will further tax sustainment capabilities that are already vulnerable to Chinese attack during a military confrontation.

Addressing CCA basing and sustainment challenges will likely require new U.S. arrangements with Japan, the Philippines, Australia, and other key countries in the Indo-Pacific theater.[150] If these countries offer operating locations for U.S. CCAs, thereby exposing themselves to the risk of Chinese attack during a conflict, then their governments will expect information about, and perhaps more direct involvement in, the CCA program. Potential asks might include production updates, sustainment planning, airworthiness evaluation, or developing interoperability with their own indigenous loyal wingman UAS programs. Some

145 Wagner, *Lightning Bugs*, 108–109.

146 Hall, "Reconnaissance Drones," 27.

147 J.H. Brown, R.G. Ollila, and R.D. Minckler, *A Survey and Technical Systems Assessment of Drone Aircraft for Tactical Reconnaissance and Surveillance* (Columbus, OH: Battelle Tactical Technology Center, February 1972), 21, https://apps.dtic.mil/sti/pdfs/AD0595802.pdf.

148 Krebs, *Did We Err*, 33.

149 Leftwich, DeBlois, and Orletsky, *Supporting Combat Power Projection*, 36.

150 Hope Hodge Seck, "Collaborative Air Combat Drones Will Head to Pacific En Masse," *The War Zone*, September 13, 2023, https://www.thedrive.com/the-war-zone/collaborative-air-combat-drones-will-head-to-pacific-en-masse.

of these actions might prove difficult to implement under current U.S. policy, meaning the U.S. government would have to look for compromise solutions with allies and partners.

Step 6: Employ Capability

Assessment: Moderate to limited progress

Rationale: The Air Force needs to make more progress with specifying CCA employment concepts. Above all, it needs to show and share its work so supportive outsiders understand the choices and tradeoffs it is making. The CCA has lived by analysis, but it can also die by analysis. Not all CCA employment assessments have met the expectations of stakeholders, leading them to question certain decisions.

The Air Force has consistently highlighted the thorough analysis of combat employment underpinning the CCA program. As Lieutenant General White stated, "Now that we've done the homework, we have all the confidence in the world that this capability is ready to move forward and it's going to change the fight."[151] The Air Force invoking analysis to argue its case is not surprising. Early-stage weapons systems need analysis to shape their direction, and leaders often cite this work when advocating for the program. Additionally, Air Force culture has long embraced analysis.[152]

Still, the CCA program has touted analysis to a greater degree than many acquisition efforts. This is probably because the aircraft lacks an antecedent system with a real-life performance record and an advocacy network that would provide prima facie justification for its creation. When a weapons program is new and not replacing something, it must fight harder to convince stakeholders it deserves to exist.[153]

The trouble is that if the CCA lives by analysis, it can also die by analysis. To retain credibility with stakeholders, CCA wargame adjudication, combat simulation, and field experimentation need to display the rigor, reproducibility, and transparency expected of high-quality research. These standards are difficult to satisfy all the time, particularly given that defense assessments involve more art than science. It should come as little surprise, then, that sources inside and outside the Air Force have reported that not all CCA analysis has met their expectations, leading them to question the rationale behind certain decisions.[154]

151 Air Force, "Background Briefing."

152 Carl H. Builder, *The Masks of War: American Military Styles in Strategy and Analysis* (Baltimore, MD: The Johns Hopkins University Press, 1989), 104–114.

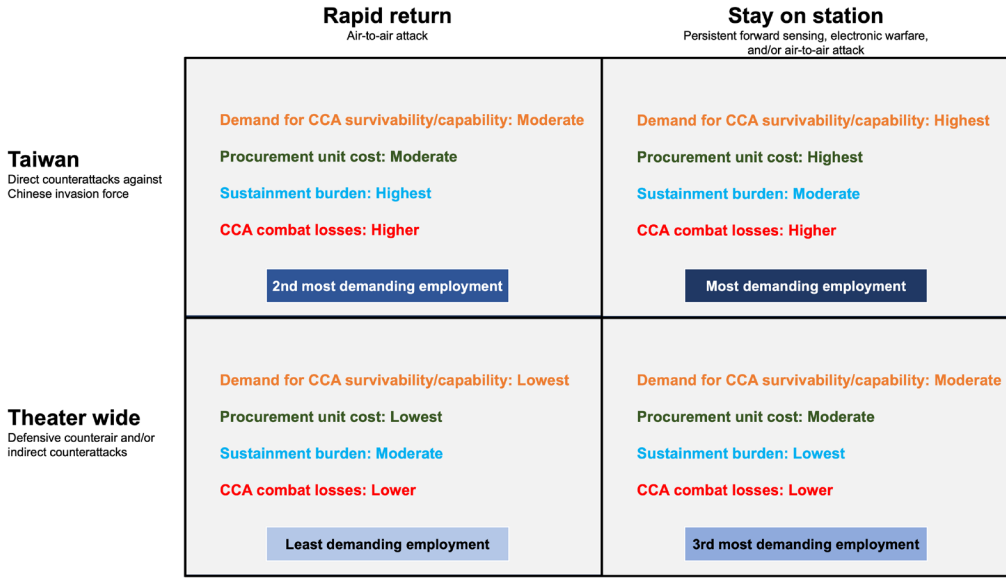
153 Michael H. Armacost, *The Politics of Weapons Innovation: The Thor-Jupiter Controversy* (New York: Columbia University Press, 1969).

154 Author's communication with industry expert from traditional defense firm, September 13, 2024.

To avoid stakeholder defections, the Air Force needs to make more progress with specifying CCA employment concepts. It should show and share its work so supportive outsiders understand the choices and tradeoffs it is making. This openness will trigger heated debates because U.S. interests, service member lives, and billions of dollars are at stake. Such intellectual ferment remains a relative strength of American strategic culture.[155] The United States benefits from its ability and willingness to use analysis to challenge assumptions, expose flaws, and consider alternatives to its own official thinking. Defense bureaucracies in authoritarian states brook such activity far less abidingly.

No Dominant Strategy illustrates the many tradeoffs flowing from employment choices. In a future U.S.–China conflict over Taiwan, a CCA fleet conducting "stay on station" persistence missions in vicinity of Taiwan would need a different aircraft design, sustainment setup, and attrition reserve than a CCA fleet launching "rapid return" hit-and-run attacks against targets outside Taiwan (Figure 12).[156]

FIGURE 12: IMPLICATIONS OF CCA EMPLOYMENT OPTIONS IN TAIWAN SCENARIO



Source: Sharp, *No Dominant Strategy*, chap. 1.

The contrasting missions could lead to different force designs. With an illustrative $13 billion procurement investment, the Air Force could purchase 200 more-survivable CCAs for $65 million apiece to stay on station near Taiwan. Alternatively, it could purchase 1,300 less-survivable CCAs for $10 million apiece to perform rapid return outside Taiwan. If CCAs were designed for balanced performance across both missions, then they would not perform

155 Sharp and Hacker, *Evaluate Like We Operate*, 27.

156 Sharp, *No Dominant Strategy*, chaps. 1 and 3.

either mission as well as they would if optimized for it. Conversely, if they were optimized for one mission, then they would not perform the other mission equally well.

In short, there is no one-size-fits-all solution to employing CCAs in a future conflict with China. The problem, as always, is how to conceptualize and choose among distinct options that lead to different outcomes. Unfortunately, Air Force public comments to date have tended to obscure this problem of choice by stressing the CCA's usefulness across many potential applications.[157] This emphasis on generality, though initially helpful for expanding the coalition of CCA supporters, has become detrimental to the program because it limits the detailed work that can be done on other steps of the end-to-end process cycle.

The Air Force has no perfect play to make with CCAs, no dominant strategy that guarantees success. Such is the nature of long-term military competition with a powerful and competent adversary such as China. Delaying force planning choices makes sense when one has reason to believe that more time will yield appreciably better decisions without incurring intolerable risk from inaction. That is not the Air Force's situation today. Universally optimal CCA employment options appear unlikely to emerge. Meanwhile, conflict with China is distinctly possible in the next decade, and authoritative studies suggest the United States could lose that war.[158]

Given this situation, the Air Force should make the best decisions about CCA employment that it can, as soon as it can, and communicate them as widely as it can. Making specific choices today, even if they are proven flawed in various ways later, beats deferring decisions in search of better answers that may never come. The future U.S. Air Force can prevail without being dealt a perfect hand by today's force planners. It has done exactly that in the past, and it can do so again. Yet, it cannot win if it does not have cards to play.

Step 7: Adapt Practices

Assessment: Moderate progress

Rationale: The Air Force has signaled its intention to work iteratively with industry to improve CCAs based on technological advances, experimentation, and operational experience. Although these commitments are encouraging, many details remain to be confirmed regarding the industrial base, contracting arrangements, and related matters. These factors will determine whether the CCA program can procure over 1,000 aircraft—and replace them quickly if lost in combat—on the Air Force's desired timeline.

The Air Force has emphasized flexibility as central to its CCA acquisition strategy. This flexibility applies both to aircraft design and its supplier approach. With aircraft design, the Air

157 Air Force, *PACAF Strategy 2023*, 9; and Air & Space Forces Association Warfare Symposium, "Advancements in Collaborative Combat Aircraft CONOPs," 2.

158 NDS Commission Final Report, 6–7.

Force wants CCAs to incorporate open architectures and modular designs so it can combine components from different vendors.[159] With suppliers, the Air Force wants continuous competition for mission systems, though it will eventually select one vendor to integrate the autonomy technology, air vehicle, and mission systems.[160] Service officials have chosen to field CCAs in multiple increments as the program advances, indicating that faster, iterative development will take precedence over slower, one-shot approaches.[161] CCA plans seek to avoid succumbing to the glacially slow, risk-averse approaches that often characterize DoD acquisition.[162]

The Lightning Bug illustrates why flexibility is essential to the CCA's success. Employment of the AQM-34 encountered recurring challenges, particularly with recovery operations early in its existence. Fixing those problems required rapid experimentation and continual improvement by both Ryan and the Air Force. Most historians credit the flexible acquisition processes granted by the Air Force with enabling rapid adaptation in response to operational outcomes. Under Big Safari's sponsorship, Ryan engineers churned out aircraft variants capable of performing photoreconnaissance, electronic intelligence collection, and surface-to-air missile suppression operations. Between 1962 and 1975, engineers created over 25 variants of the AQM-34 to fulfill various missions, showcasing the aircraft's adaptability.[163]

The AQM-34's contracting arrangements, which appointed Ryan as the sole-source supplier, are not necessarily ideal for the CCA program. Vendors competing for each CCA contract and the Air Force awarding contract tranches to different companies will better achieve the iterative development envisioned by planners.[164] That said, close collaboration between the government and industry did enable the AQM-34's success. That collaboration is worth re-creating today with CCAs.

Ultimately, the CCA program's success will depend on the agreements reached and performance demonstrated by both contractor and Air Force personnel.[165] From industry's perspective, though repeated competitions for each increment support quicker development, they also impede firms from developing viable business cases and long-term production plans that would drive costs down through efficiency.[166]

159 Air Force, "Background Briefing."

160 John A. Tirpak, "Competition Defines New Collaborative Combat Aircraft Program Now, But Not Forever," *Air & Space Forces Magazine*, September 18, 2023, https://www.airandspaceforces.com/competition-collaborative-combat-aircraft-program/.

161 Chris Gordon, "Air Force Futures Boss Reveals New CCA Details, Including Potential Aerial Refueling," *Air & Space Forces Magazine*, November 15, 2023, https://www.airandspaceforces.com/air-force-futures-new-details-cca-aerial-refueling/.

162 Christian D. Brose, *Moneyball Military: An Affordable, Achievable, and Capable Alternative to Deter China* (Stanford, CA: Hoover Institution, September 2023), 3, https://www.hoover.org/sites/default/files/research/docs/Brose_MoneyballMilitary_web_230921.pdf.

163 Wagner, *Lightning Bugs,* 213.

164 Author's communication with industry expert from traditional defense firm, July 27, 2023.

165 Tirpak, "Kendall: Air Force Wants"; and Air Force, "Background Briefing."

166 Author's communication with industry expert from traditional defense firm, August 22, 2024.

The CCA program's ambitions of fielding over 1,000 aircraft on a relatively short timeline will surely stress the industrial base, contracting arrangements, and related aspects of the acquisition enterprise. According to some industry experts, establishing the necessary supply chain will require the Air Force to make significant investments, including tapping the commercial market and nontraditional defense firms to buy jet engines, additive manufacturing, thermoplastics, and other inputs.[167] DoD's longstanding shortcomings at accessing commercial markets, including with software technology, pose a formidable obstacle to CCA development.[168] It remains to be seen whether the Air Force can erect contracting processes that allow quick-turn improvements to CCAs in response to real-world military crises.

Conclusion

Depending on one's perspective, this chapter's findings could be encouraging or concerning. To optimists, the fact that earlier steps display more progress than later steps indicates the Air Force is hitting CCA milestones sequentially over time. If that continues, the results will look incrementally better in a year or two. To pessimists, the interdependence of the three steps featuring the most laggard progress (develop, deploy, employ) suggests those steps must improve together, or not at all. If that is the case, then piecemeal progress has run its course. The Air Force now must improve everything everywhere all at once.

The author takes the optimistic view. The CCA program can succeed by continuing to make discrete progress. Pessimists are right about the interdependence of steps, but expecting a global solution that turns the entire stoplight chart green in one stroke of genius is unrealistic. Criticizing the Air Force for not having such a solution is unfair. The CCA is a novel capability. It is not a run-of-the-mill acquisition effort. It has advanced significantly in just two years. Conceptual breakthroughs often come in fits and starts. The Air Force can find workable approaches if it stays on target.

The CCA program has freedom to maneuver and err, though it must self-correct quickly to meet the pressing threat from China. This freedom is rooted in perception and politics. Rightly or wrongly, the CCA has become a symbol of the desire of nearly everyone to break free of the Pentagon's acquisition status quo.[169] Buoyed by this larger meaning, the program will probably receive the benefit of the doubt from its political overseers.[170] They will criti-

167 John A. Tirpak, "Air Combat Command Planner: Misconception that CCAs Will Be 'Attritable,'" *Air & Space Forces Magazine*, March 8, 2023, https://www.airandspaceforces.com/ccas-not-attritable-acc-planner/.

168 Jeff Decker and Eric Li, "How Software Companies Can Enter the U.S. Defense Market," *Harvard Business Review*, July 14, 2023, https://hbr.org/2023/07/how-software-companies-can-enter-the-u-s-defense-market.

169 NDS Commission Final Report, 29–36; Shyam Sankar, *The Defense Reformation* (Denver, CO: Palantir, October 31, 2024), https://www.18theses.com/The%20Defense%20Reformation.pdf; and Roger Wicker, *Restoring Freedom's Forge: American Innovation Unleashed*, December 19, 2024, https://www.wicker.senate.gov/2024/12/senator-wicker-announces-pentagon-reform-and-innovation-proposal.

170 Lamothe, Horton, and Natanson, "Trump Administration Orders."

cize and adjust it as they see fit, but they will not want to extinguish a capability symbolizing what is, to many, the necessary direction for the future U.S. military.

The CCA thus enjoys implicit political support that ought to make other weapons program managers jealous. The Air Force has used this gift well. It must not let up.

CHAPTER 4

Ten Unanswered Questions

Fielding a novel military capability like the CCA is incredibly difficult. It requires technology, resources, politics, and planning all coming together in the right amounts at the right times. Even then, success can prove elusive. Given the difficulty of the undertaking, the Air Force deserves tremendous credit for advancing the CCA program as far and as fast as it has—even if much more work remains to be done.

An assessment covering as much ground as this one always raises more questions than it can answer. The report is far closer to the first word than the last word on CCAs. That being the case, it is fitting to conclude by listing ten questions it did not address. Some emerged from this research. Others came from CSBA colleagues and outside experts who reviewed drafts of the report. These questions should help the Air Force and analysts peer around some corners that they might not otherwise.

1. The Air Force considers CCAs to be a complement to manned aircraft, but how long can the service hold out against the rising tide of popular commentary that cites the Ukraine War as proof that less-expensive UAS in larger numbers are a substitute for more-expensive manned aircraft in smaller numbers?[171]

2. If CCAs improve manned aircraft effectiveness and reduce manned aircraft attrition, as the Air Force claims, will that become a rationale for cutting the size of the manned aircraft fleet? As the argument will go, if each manned aircraft is more effective and survivable (thanks to CCAs), then the Air Force can generate the same collective effectiveness with fewer manned aircraft.

171 Evan Montgomery, Travis Sharp, and Tyler Hacker, "Quality Has a Quality All Its Own: The Virtual Attrition Value of Superior-Performance Weapons," *War on the Rocks*, June 19, 2024, https://warontherocks.com/2024/06/quality-has-a-quality-all-its-own-the-virtual-attrition-value-of-superior-performance-weapons/.

3. To what extent is the platform tradeoff really about CCA versus F-16 rather than CCA versus F-35 or NGAD? In a future U.S.–China conflict, the CCA and F-16 might perform similar supporting roles for more advanced fighters.
4. Will CCA organization, sustainment, and operation emulate existing manned aircraft practices or will manned aircraft eventually emulate CCA practices?
5. Will CCAs belong to the fighter squadrons they fly with, or will they have their own squadrons?
6. Will CCAs use the same maintenance and support personnel as manned aircraft, or will CCA personnel and manned aircraft personnel be separate?
7. If CCAs do not replace any manned aircraft and do not rely on any personnel assigned to manned aircraft, then will the Air Force have to increase end strength (personnel) to integrate CCAs into the force?
8. Will personnel maintain active custody of CCAs during operational pauses (i.e., when CCAs are not performing missions for manned aircraft), or will CCAs self-maintain during pauses without being in a human controller's custody?
9. Should a given air base host manned aircraft, CCAs, or both?
10. What lessons for the CCA program can be derived from studying escort fighters in World War II?

APPENDIX A

Supporting Budget Data

Sources for Research and Development Funding Projection (Figure 5)

- **Collaborative combat aircraft (CCA)**: Air Force, *FY 2024 Budget Estimates, Research, Development, Test & Evaluation,* vol. 2, March 2023, 415, https://www.saffm.hq.af.mil/Portals/84/documents/FY24/Research%20and%20Development%20Test%20and%20Evaluation/FY24%20Air%20Force%20Research%20and%20Development%20Test%20and%20Evaluation%20Vol%20II.pdf?ver=pYOQLrjX71gVe8w6FCJOwg%3d%3d.
- **Long-range strike bomber**: Air Force, *FY 2013 Budget Estimates, Research, Development, Test & Evaluation,* vol. 2, February 2012, 193, https://www.saffm.hq.af.mil/Portals/84/documents/FY13/AFD-120207-047.pdf?ver=2016-08-24-090009-980.
- **Next Generation Air Dominance (NGAD)**: Air Force, *FY 2018 Budget Estimates, Research, Development, Test & Evaluation,* vol. 2, May 2017, 179, https://www.saffm.hq.af.mil/Portals/84/documents/Air%20Force%20Research,%20Development,%20Test%20and%20Evaluation%20Vol-II%20FY18.pdf?ver=2017-05-23-160041-060.
- **Ground-based strategic deterrent**: Air Force, *FY 2017 Budget Estimates, Research, Development, Test & Evaluation,* vol. 2, February 2016, 235, https://www.saffm.hq.af.mil/Portals/84/documents/FY17/AFD-160208-051.pdf?ver=2016-08-24-102123-043.
- **Advanced Battle Management System**: Air Force, *FY 2021 Budget Estimates, Research, Development, Test & Evaluation,* vol. 2, February 2020, 93, https://www.saffm.hq.af.mil/Portals/84/documents/FY21/RDTE_/FY21%20Air%20Force%20Research%20Development%20Test%20and%20Evaluation%20Vol%20II.pdf?ver=2020-02-12-145218-377.

Sources and Assumptions for Aircraft Procurement Estimate (Figure 6)

TABLE 4: AIRCRAFT COSTS AND QUANTITIES FOR PROCUREMENT SPENDING ESTIMATE

Aircraft	Unit cost (FY24$)	Annual procurement maximum quantity	Total quantity, FY28–FY38
CCA [172]	$9m / $23m / $37m	150 (by FY30)	1,000
B-21 [173]	$768m	10 (by FY29)	108
F-35A [174]	$110m	48	527
NGAD [175]	$276m	20 (by FY33)	175
E-7 [176]	$635m	5	19
KC-46 [177]	$181m	15	70
T-7 [178]	$21m	36	293

Sources for Selected Weapons Systems Lifecycle Costs (Figure 10)

- **F-35**: Department of Defense (DoD), *Modernized Selected Acquisition Report (MSAR) F-35 Lightning II*, December 2023, 22, 23, 28, https://www.esd.whs.mil/Portals/54/Documents/FOID/Reading%20Room/Selected_Acquisition_Reports/FY_2023_SARS/F-35%20MSAR%20Dec%202023.pdf.
- **Sentinel**: DoD, *MSAR LGM-35A Sentinel*, December 2023, 13, 18, https://www.esd.whs.mil/Portals/54/Documents/FOID/Reading%20Room/Selected_Acquisition_Reports/FY_2023_SARS/LGM-35A_Sentinel_MSAR_Dec_2023.pdf.

172 Assumed procurement rate of 150 is smaller than notionally suggested in public discussions. Increasing the rate would amplify the bow wave. John A. Tirpak, "Air Combat Command Planner: Misconception that CCAs Will Be 'Attritable,'" *Air & Space Forces Magazine*, March 8, 2023, https://www.airandspaceforces.com/ccas-not-attritable-acc-planner/.

173 Unit cost based on cost target ($550m in FY10$) adjusted for inflation. Assumed procurement rate of ten is smaller than notionally suggested in public reports. Increasing the rate would amplify the bow wave. Christopher J. Bowie, *Air Power Metamorphosis: Rethinking Air Force Combat Force Modernization* (Washington, DC: Center for Strategic and Budgetary Assessments, March 2023), 22, https://csbaonline.org/uploads/documents/CSBA8342_(Air_Power_Metamorphosis_Report)_final_web.pdf.

174 Air Force, *FY 2025 Budget Estimates, Aircraft Procurement*, vol. 1, March 2024, 9, https://www.saffm.hq.af.mil/Portals/84/documents/FY25/FY25%20Air%20Force%20Aircraft%20Procurement%20Vol%20I.pdf?ver=trnnCwkcSenGdKVniZvWHQ%3D%3D.

175 Assumed procurement rate of 20 would keep NGAD annual spending roughly balanced with F-35A annual spending. Alex Hollings, "Why America's New NGAD Fighter Could Be a Bargain, Even at $300 Million Each," *Sandboxx*, July 6, 2023, https://www.sandboxx.us/news/airpower/why-americas-new-ngad-fighter-could-be-a-bargain-even-at-300-million-each/.

176 Assumed procurement rate of five would keep E-7 annual spending roughly balanced with KC-46 annual spending. UK House of Commons Defence Committee, *It Is Broke—And It's Time to Fix It: The UK's Defence Procurement System*, July 11, 2023, 16, https://committees.parliament.uk/publications/40911/documents/199247/default/.

177 Assumed procurement rate reflects continuing purchases beyond program of record to fulfill bridge requirement. Air Force, *FY 2025 Budget Estimates, Aircraft Procurement*, vol. 1, 43.

178 Air Force, *FY 2025 Budget Estimates, Aircraft Procurement,* vol. 1, 67.

- **KC-46A**: DoD, *MSAR KC-46A Tanker Modernization*, December 2023, 23, 27, https://www.esd.whs.mil/Portals/54/Documents/FOID/Reading%20Room/Selected_Acquisition_Reports/FY_2023_SARS/KC-46A_MSAR_Dec_2023.pdf.
- **NSSL**: DoD, *MSAR National Security Space Launch*, December 2023, 16, 20, https://www.esd.whs.mil/Portals/54/Documents/FOID/Reading%20Room/Selected_Acquisition_Reports/FY_2023_SARS/NSSL_MSAR_Dec_2023.pdf.
- **F-15 EX**: DoD, *MSAR F-15 EX MDAP*, December 2023, 12, 16, https://www.esd.whs.mil/Portals/54/Documents/FOID/Reading%20Room/Selected_Acquisition_Reports/FY_2023_SARS/F-15_EX_MDAP_MSAR_Dec_2023.pdf.
- **HH-60W**: DoD, *MSAR HH-60W Jolly Green II*, December 2023, 15, 19, https://www.esd.whs.mil/Portals/54/Documents/FOID/Reading%20Room/Selected_Acquisition_Reports/FY_2023_SARS/HH-60W_MSAR_Dec_2023.pdf.
- **JASSM**: DoD, *MSAR Joint Air-to-Surface Standoff Missile*, December 2023, 15, 18, https://www.esd.whs.mil/Portals/54/Documents/FOID/Reading%20Room/Selected_Acquisition_Reports/FY_2023_SARS/JASSM_MSAR_Dec_2023.pdf.
- **LRSO**: DoD, *MSAR Long Range Stand Off Weapon*, December 2023, 12, 16, https://www.esd.whs.mil/Portals/54/Documents/FOID/Reading%20Room/Selected_Acquisition_Reports/FY_2023_SARS/LRSO_MSAR_Dec_2023.pdf.
- **SDB II**: DoD, *MSAR Small Diameter Bomb Increment II*, December 2023, 19, 23, https://www.esd.whs.mil/Portals/54/Documents/FOID/Reading%20Room/Selected_Acquisition_Reports/FY_2023_SARS/SDB_II_MSAR_Dec_2023.pdf.
- **AIM-9X Blk II**: DoD, *MSAR AIM-9X Block II Sidewinder*, December 2023, 17, 21, https://www.esd.whs.mil/Portals/54/Documents/FOID/Reading%20Room/Selected_Acquisition_Reports/FY_2023_SARS/AIM-9X%20Blk%20II%20MSAR%20Dec%202023.pdf.

LIST OF ACRONYMS

ACE	agile combat employment
CATS	Combat Airpower Teaming System
CCA	collaborative combat aircraft
CSBA	Center for Strategic and Budgetary Assessments
DoD	U.S. Department of Defense
E2EPC	end-to-end process cycle
FCAS	Future Combat Air System
FY	fiscal year
GCAP	Global Combat Air Programme
ISR	intelligence, surveillance, and reconnaissance
MARS	mid-air retrieval system
MSAR	modernized selected acquisition report
NDS	National Defense Strategy
NGAD	Next Generation Air Dominance
O&S	operation and support
RDT&E	research, development, test, and evaluation
UAS	unmanned aircraft system

CSBA
Center for Strategic and Budgetary Assessments

1667 K Street, NW, Suite 900
Washington, DC 20006
Tel. 202.331.7990 • Fax 202.331.8019
www.csbaonline.org