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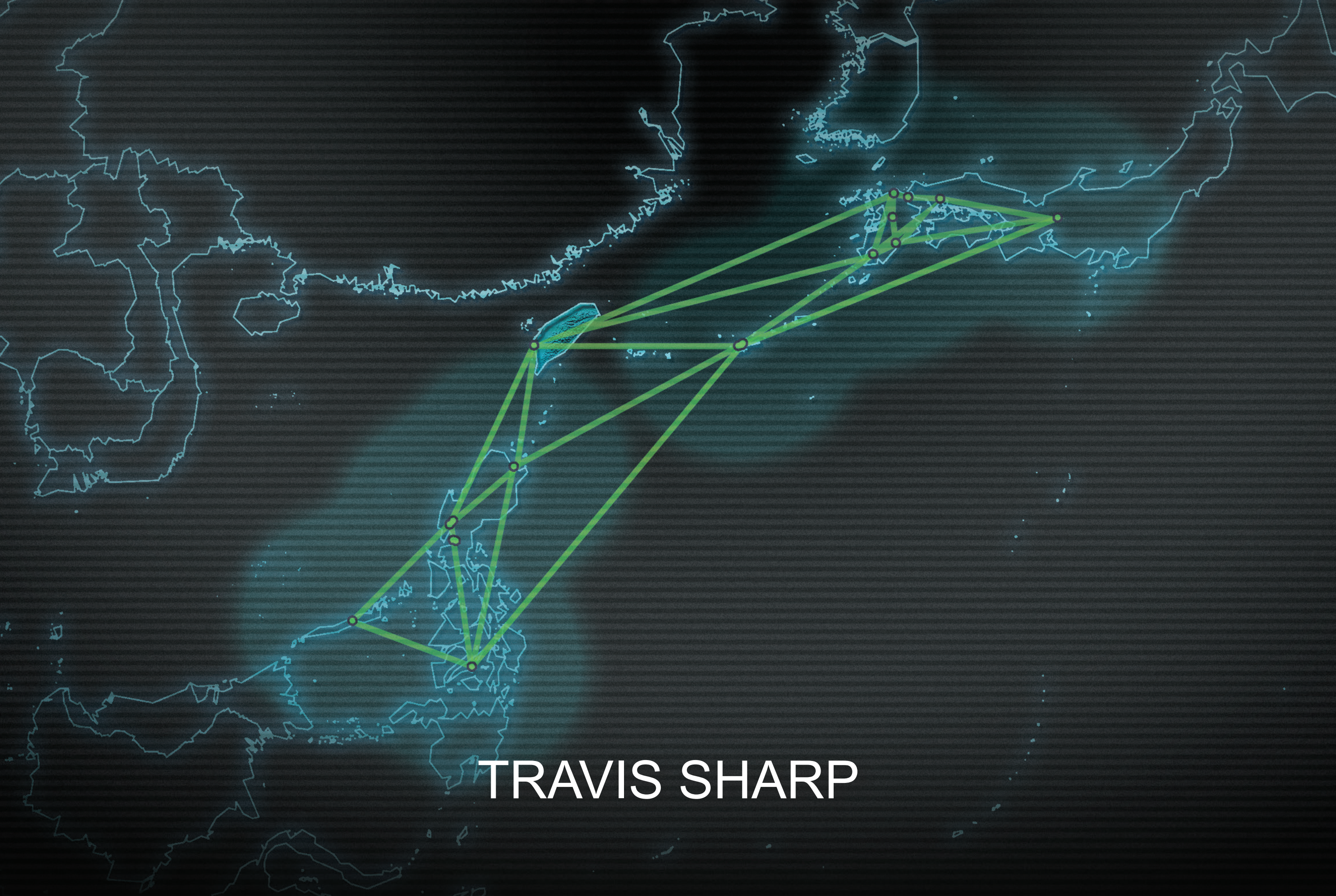
NO DOMINANT STRATEGY FOR AIR DOMINANCE

COLLABORATIVE COMBAT AIRCRAFT EMPLOYMENT, BASING, AND SORTIE GENERATION IN A TAIWAN SCENARIO



TRAVIS SHARP

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Cover graphic: Cover design by CSBA staff.

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Executive Summary

This report uses a simple sortie-generation model to explore options for employing and basing U.S. collaborative combat aircraft (CCA) during a Chinese attempt to invade Taiwan in the early to mid-2030s. It has been prepared as a companion volume to the Center for Strategic and Budgetary Assessments' larger study of the CCA program, *Ready Player None? An End-to End Assessment of the Air Force Collaborative Combat Aircraft Program*.[1]

This report first illustrates the effects of CCA mission profile, combat air patrol geographic emphasis, and basing dispersion on sortie generation to show the range of operational possibilities and logistical burdens. It then illustrates how combat attrition might affect CCA fleet size and identifies the resulting quantity–cost tradespace.

The report highlights key variables requiring exploration in future research using higher fidelity models. Leaders should not make programmatic decisions based solely on the report because it does not incorporate blue-on-red force exchanges, manned–unmanned teaming, aerial refueling, or other factors requiring scrutiny. In line with the goal of *Ready Player None?*, however, it can help leaders ask good questions when developing CCA plans and assessments.

No One-Size-Fits-All Solution for CCAs

In game theory, a dominant strategy is one that always yields a higher payoff than alternative strategies, regardless of what the opponent does. This report shows there is no dominant strategy for using CCAs to fight China. In other words, there does not appear to be an optimal way to employ and base the CCA fleet in a Taiwan scenario. If CCAs are designed for balanced performance across missions, then they will not perform any mission as well as they could if optimized for it. Conversely, if they are optimized for one mission, then they will not perform other missions equally well.

1 Travis Sharp, *Ready Player None? An End-to End Assessment of the Air Force Collaborative Combat Aircraft Program* (Washington, DC: Center for Strategic and Budgetary Assessments, May 2025).

Although this finding may seem self-evident, it cuts against the Air Force's tendency to stress the CCA's broad utility "across diverse missions" while downplaying the fact that tradeoffs must be made to excel at any given mission.[2] Exemplifying this tendency, Lieutenant General Dale White, a top Air Force acquisition official, once said about CCA design, "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 mission."[3] 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 Air Force's emphasis on the CCA's many potential roles made sense in the program's initial stage. After all, Air Force leaders were contemplating novel ideas and needed to generate enthusiasm for CCAs inside and outside the service. At this point, however, generality about CCA missions comes across not as thoughtful but rather as indecisive, particularly in the face of China's rapidly advancing military power.

The Air Force should make and communicate specific choices about how it intends to deploy and employ CCAs. Although it cannot publicly share all the details due to classification, it can disclose far more information than it has so far with force planners, industry, Congress, and other key stakeholders. This report identifies several areas where near-term decisions by the Air Force are most needed because they will drive tradeoffs in aircraft design, logistical support, and force posture.

2 Air Force, *PACAF Strategy 2023: Evolving Airpower*, September 2023, 9, https://www.af.mil/Portals/1/documents/2023SAF/PACAF_Strategy_2030.pdf; 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/.

3 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.

CHAPTER 1

Rapid Return or Stay on Station? Options for CCA Employment and Basing

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. 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.[4] 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.[5] When teamed with CCAs, manned aircraft will suffer fewer losses and achieve more kills against Chinese air threats, according to service officials.[6]

The Air Force has cited forward sensing, air-to-air attack, and electronic warfare as the CCA's envisioned missions.[7] The Air Force views the CCA as part of a future ecosystem of autonomous unmanned collaborative platforms that will perform mobility, training, and

4 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/.

5 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.

6 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.

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

other missions.[8] 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 within NGAD reflects the Air Force's view of it as a complement to manned aircraft, particularly fighters.

Brief Review of Employment and Basing Literature

Many studies have explored the complex tradeoffs associated with choosing how to employ and base combat aircraft. Starting with Albert Wohlstetter's research in the early 1950s, analysts at RAND and elsewhere have dissected how fighting concepts and basing locations affect vulnerability to enemy attack, aircraft design, logistics, political relationships with allies, and the budgetary costs embedded in all of the above.[9]

Over the past 20 years, American interest in this research has surged as China's growing military strength has threatened U.S. and allied airpower in the Western Pacific.[10] Recent work has studied site selection for the Air Force's agile combat employment (ACE) concept, U.S. posture in the Indo-Pacific region, and ground support in highly contested environments.[11] Unsurprisingly, Chinese analysts with People's Liberation Army ties also have published research on these and related topics.[12]

8 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/.

9 Albert Wohlstetter, *Economic and Strategic Considerations in Air Base Location: A Preliminary Review* (Santa Monica, CA: RAND Corporation, 1951), https://www.rand.org/pubs/documents/D1114.html; and Alan J. Vick and Mark Ashby, *Winning the Battle of the Airfields: Seventy Years of RAND Analysis on Air Base Defense and Attack* (Santa Monica, CA: RAND Corporation, February 2021), https://www.rand.org/pubs/research_reports/RRA793-1.html.

10 Christopher J. Bowie, *The Anti-Access Threat and Theater Air Bases* (Washington, DC: Center for Strategic and Budgetary Assessments [CSBA], September 2002), https://csbaonline.org/research/publications/the-anti-access-threat-and-theater-air-bases; and Vick and Ashby, *Winning the Battle of the Airfields*, 10, 54–79.

11 Zachary T. Moer et al., "Contested Agile Combat Employment: A Site-Selection Methodology," *Air & Space Operations Review* 1, no. 3, Fall 2022, 62–77; Carl Rehberg and Josh Chang, *Moving Pieces: Near-Term Changes to Pacific Air Posture* (Washington, DC: CSBA, November 2022), https://csbaonline.org/research/publications/moving-pieces-near-term-changes-to-pacific-air-posture; Robert D. Davis, "Forward Arming and Refueling Points for Fighter Aircraft: Power Projection in an Anti-access Environment," *Air & Space Power Journal* 28, no. 5, September–October 2014, 5–28; and 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.

12 Fuqin Yang, Jinhua Li, and Mingzhu Zhu, "Optimization Allocation of Aerospace Ground Support Vehicles for Multiple Types of Military Aircraft," *Advanced Computational Methods in Energy, Power, Electric Vehicles, and Their Integration* 763, 2017, 719–728; and Tao Ma, Chengyu Ju, and Huaigeng Qu, "Simulation and Verification Method of Aircraft High Intensity Dispatch Capability," *Proceedings of the 5th China Aeronautical Science and Technology Conference* 821, 2021, 271–280.

Taiwan Scenario, CCA Inventory, and Output Variable (Sorties)

This report's analysis considers a Chinese attempt to invade Taiwan in the early to mid-2030s. The invasion targets Taiwan's southwest coast in the vicinity of Tainan, a potential Chinese landing area.[13] Tainan Airport functions as a generic center point for collaborative combat aircraft (CCA) combat air patrols (CAPs) in the Taiwan southwest coast sector.

The conflict timeframe aligns with the U.S. CCA inventory reaching a significant size. The analysis assumes the United States has 500 CCAs in the Indo-Pacific theater available for use in a Taiwan contingency. A theater inventory of 500 CCAs would be two thirds of the U.S. global CCA inventory in the early to mid-2030s, according to the future aircraft procurement estimate featured in *Ready Player None?*[14]

The analysis's output variable is the number of CCA sorties generated in 24 hours from all basing locations (see Chapter 2).[15] As modeled here, sortie generation primarily depends on three input variables: CCA mission profile, CAP geographic emphasis, and basing dispersion.

Input Variable 1: CCA Mission Profile

CCAs can fly two mission profiles: rapid return or stay on station. Human controllers would supervise CCAs under both profiles. The analysis only evaluates CCAs flying one profile or the other. Future research could explore mixed profiles.

Under rapid return, a CCA flies to the target area (or as close as it can, given its combat radius) and then returns to base without prolonged loitering on station. Rapid return exemplifies CCAs performing air-to-air kinetic attacks in which they fly to the target sector, fire missiles at enemy aircraft, and return home as quickly as possible. Rapid return maximizes sortie generation because flight times are shorter. Thus, more sorties can occur in every 24 hour-period.

With stay on station, in contrast, a CCA flies to the target (or as close as possible) and then remains on station until fuel considerations require returning to base. Stay on station illustrates CCAs performing forward sensing or electronic warfare roles in which they persistently reconnoiter and/or sanitize the target sector. CCAs could also conduct air-to-air attacks under stay on station, as long as they persisted in the target area before or after

13 Micah McCartney, "Map Shows Taiwan's Beaches Vulnerable to Chinese Invasion," *Newsweek*, December 28, 2023, https://www.newsweek.com/taiwan-beaches-higher-risk-invasion-china-1851899.

14 Travis Sharp, *Ready Player None? An End-to End Assessment of the Air Force Collaborative Combat Aircraft Program* (Washington, DC: CSBA, May 2025), chap. 3. The report estimated that the collaborative combat aircraft (CCA) inventory would total 750 aircraft worldwide in fiscal year 2033. Assigning 500 of 750 globally available CCAs (66 percent) to an Indo-Pacific contingency would only moderately exceed aircraft allocation rates from the Gulf War. *Gulf War Air Power Survey* (*GWAPS*), vol. 3, 1993, 29–30, https://media.defense.gov/2010/Sep/27/2001329815/-1/-1/0/gulf_war_air_power_survey-vol3.pdf.

15 A sortie is defined as one aircraft flying from a base to perform a mission under enemy threat. If four aircraft launch from a base to perform a mission together, that activity would represent four sorties. Boghos D. Sivazlian, "Aircraft Sortie Effectiveness Model," *Naval Research Logistics*, 36, no. 2, April 1989, 127.

launching missiles. Stay on station minimizes sortie generation because flight times are longer, so fewer sorties can occur in every 24-hour period.

The different mission profiles would require CCAs with different capabilities and costs. To stay on station with enemy forces nearby, CCAs would need improved all-aspect signature management, passive sensing, data links, and power generation—or a concept of employment that somehow obviated these needs. The unit cost of CCA variants with such capabilities might greatly exceed the $10 million to $30 million cost targets emphasized by the Air Force.[16]

Additionally, the mission profiles would probably impose different sustainment burdens. Because CCAs would fly more sorties under rapid return, they also would consume larger amounts of fuel, munitions, and maintenance (including software upkeep) during each 24-hour period. Supplying these requirements at CCA bases would tax logistics networks.

Input Variable 2: CAP Geographic Emphasis

CCA CAPs feature two geographic emphases: Taiwan or other theaterwide areas. Unlike with mission profile, the options are not mutually exclusive. Theaterwide sorties still occur under the Taiwan option and vice versa. The options therefore resemble designating main and supporting efforts in military planning.

Emphasizing Taiwan illustrates employing CCAs as a front-line stopping force to blunt the Chinese invasion. This option would support directly counterattacking the forwardmost echelons of the Chinese assault.

In contrast, accentuating theaterwide areas means employing CCAs more heterogeneously, which would include attacking targets outside the invasion zone, interdicting Chinese resupply, or protecting high-value U.S. air assets such as refueling tankers. This option involves using CCAs to conduct defensive counterair missions against Chinese aircraft or indirect counterattacks against Chinese forces outside the conflict epicenter.

The different geographic emphases would amplify the demands placed on CCA capabilities and sustainment (Figure 1). If stay on station demands more capability to survive than rapid return, as hypothesized in the Mission Profile section, then stay on station in vicinity of Taiwan would demand even more capability relative to stay on station in theaterwide areas. Increasing CCA capability would make the aircraft more expensive.

16 Sharp, *Ready Player None?*, chap. 1; and Joseph Trevithick, "Second Batch of Air Force CCA Drones Could Be 20 to 30 Percent Pricier Than the First," *The War Zone*, January 10, 2025, https://www.twz.com/air/second-batch-of-air-force-cca-drones-could-be-20-to-30-percent-pricier-than-the-first.

FIGURE 1: IMPLICATIONS OF CCA EMPLOYMENT OPTIONS IN TAIWAN SCENARIO

	Rapid return Air-to-air attack	**Stay on station** Persistent forward sensing, electronic warfare, and/or air-to-air attack
Taiwan Direct counterattacks against Chinese invasion force	Demand for CCA survivability/capability: Moderate Procurement unit cost: Moderate Sustainment burden: Highest CCA combat losses: Higher **2nd most demanding employment**	Demand for CCA survivability/capability: Highest Procurement unit cost: Highest Sustainment burden: Moderate CCA combat losses: Higher **Most demanding employment**
Theater wide Defensive counterair and/or indirect counterattacks	Demand for CCA survivability/capability: Lowest Procurement unit cost: Lowest Sustainment burden: Moderate CCA combat losses: Lower **Least demanding employment**	Demand for CCA survivability/capability: Moderate Procurement unit cost: Moderate Sustainment burden: Lowest CCA combat losses: Lower **3rd most demanding employment**

Source: CSBA analysis.

Meanwhile, if rapid return's higher sortie rate increases logistical needs relative to stay on station, then rapid return near Taiwan would tax sustainment more than rapid return in theaterwide areas. For example, CCAs returning from Taiwan's skies might need more intensive maintenance or software updating before returning to the threat-saturated battlespace over Taiwan. In addition, CCA combat attrition in vicinity of Taiwan would probably exceed attrition in theaterwide areas, a point revisited in Chapter 3.

Input Variable 3: Basing Dispersion

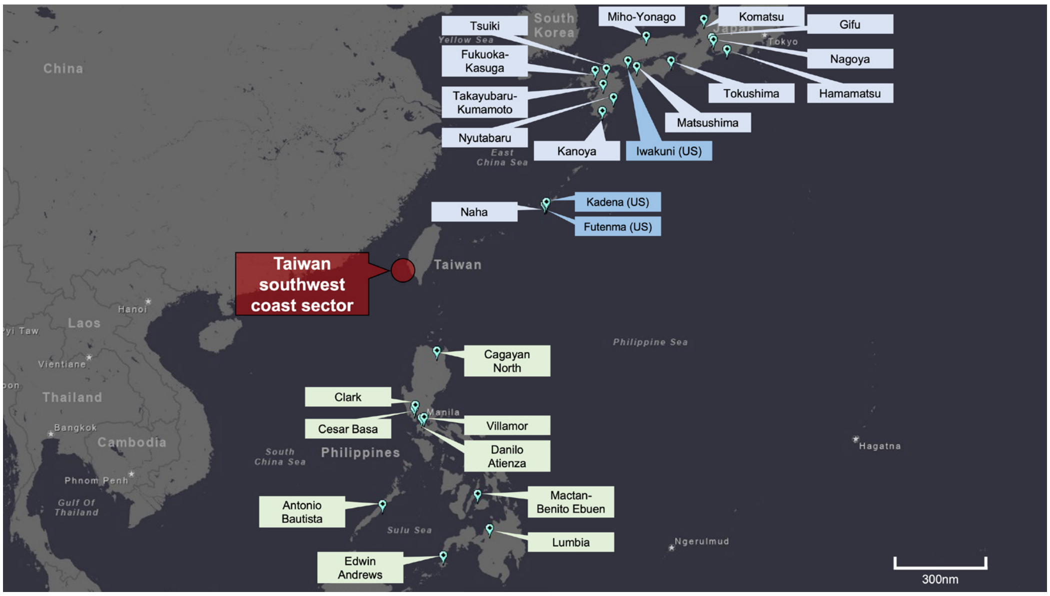
The analysis selected a sample of 25 sites from which 500 CCAs might operate during a U.S. military campaign to help defend Taiwan (Figure 2 and Table 1). Three considerations guided the site selections.

- First, the analysis chose sites located close enough to Taiwan that sortieing CCAs with an assumed combat radius of 750 nautical miles (nm) could enter (or nearly enter) Taiwanese airspace, conduct their missions, and return to base without aerial refueling. This consideration led to focusing on sites in Japan and the Philippines.

- Second, the analysis selected sites with runways at least 6,000 feet in length to support CCA operations. Although CCAs are likely to be capable of using shorter runways, leading studies have used this or a similar parameter, and the analysis followed suit.[17]

- Third, the analysis sought a mix of recognized and lesser-known sites to mirror the dispersal approach of the Air Force's ACE concept. Recognized sites included existing fighter bases and locations covered under the American-Philippine Enhanced Defense Cooperation Agreement. Manned aircraft might simultaneously operate from the selected sites.

FIGURE 2: 25 OPERATING SITES IN JAPAN AND THE PHILIPPINES



Source: CSBA analysis of Janes data.

Notes: Blue shading indicates sites in Japan and green shading indicates sites in the Philippines. Kadena, Futenma, and Iwakuni are U.S. main bases.

17 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 21:38, https://mitchellaerospacepower.org/episode-193-high-tempo-airpower-generation/; 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), 22, https://mitchellaerospacepower.org/the-need-for-collaborativecombat-aircraft-for-disruptive-air-warfare; Davis, "Forward Arming," 14; and John M. Halliday, *Tactical Dispersal of Fighter Aircraft: Risk, Uncertainty, and Policy Recommendations* (Santa Monica, CA: RAND Corporation, 1987), 4, https://www.rand.org/pubs/notes/N2443.html.

TABLE 1: GEOCOORDINATES AND SORTIE RATES OF 25 OPERATING SITES

Site #	Site name	Country	Operator	MGRS	One-way distance (nm) to Taiwan	Taiwan airspace within CCA combat radius (<750nm)	Max sorties per CCA in 24hrs (rapid return)	Min sorties per CCA in 24hrs (stay on station)	Max loiter hours per CCA sortie (stay on station)
1	Futenma	Japan	United States	52RCQ7534206508	457	Yes	2.1	1.3	7.6
2	Iwakuni	Japan	United States	53SKT4512781502	921	No	2.3	1.7	3.5
3	Kadena	Japan	United States	52RCQ7694415825	460	Yes	2.1	1.3	7.5
4	Fukuoka-Kasuga	Japan	Japan	52SFC3456516531	835	Yes	2.1	1.6	3.5
5	Gifu	Japan	Japan	53SPV6979818351	1145	No	2.1	1.6	3.5
6	Hamamatsu	Japan	Japan	53SQU4744048675	1157	No	2.1	1.6	3.5
7	Kanoya	Japan	Japan	52RFV7499072071	759	Yes	2.1	1.6	3.5
8	Komatsu	Japan	Japan	53SPA2620228591	1164	No	2.1	1.6	3.5
9	Matsushima	Japan	Japan	53SKT8712345378	926	No	2.1	1.6	3.5
10	Miho-Yonago	Japan	Japan	53SLV4002929060	1013	No	2.1	1.6	3.5
11	Nagoya	Japan	Japan	53SPV7503303019	1143	No	2.1	1.6	3.5
12	Naha	Japan	Japan	52RCP6469698077	451	Yes	2.0	1.2	7.6
13	Nyutabaru	Japan	Japan	52SGA3139452334	810	Yes	2.1	1.6	3.5
14	Takayubaru-Kumamoto	Japan	Japan	52SFB7343934184	817	Yes	2.1	1.6	3.5
15	Tokushima	Japan	Japan	53SMT6367176862	1011	No	2.1	1.6	3.5
16	Tsuiki	Japan	Japan	52SFC8905129084	859	Yes	2.1	1.6	3.5
17	Antonio Bautista	Philippines	Philippines	50PPR9291777399	794	Yes	2.1	1.6	3.5
18	Cagayan North	Philippines	Philippines	51QUA6674110668	298	Yes	1.9	1.1	9.8
19	Cesar Basa	Philippines	Philippines	51PTS3051058170	477	Yes	2.0	1.2	7.3
20	Clark	Philippines	Philippines	51PTS3640579525	465	Yes	2.0	1.2	7.4
21	Danilo Atienza	Philippines	Philippines	51PTS7476303549	507	Yes	2.0	1.3	6.9
22	Edwin Andrews	Philippines	Philippines	51NUH9661365481	964	No	2.1	1.6	3.5
23	Lumbia	Philippines	Philippines	51PXK7728129769	906	No	2.1	1.6	3.5
24	Mactan-Benito Ebuen	Philippines	Philippines	51PXM0678739844	786	Yes	2.1	1.6	3.5
25	Villamor	Philippines	Philippines	51PTS8699006099	507	Yes	2.0	1.3	6.9

Source: CSBA analysis.

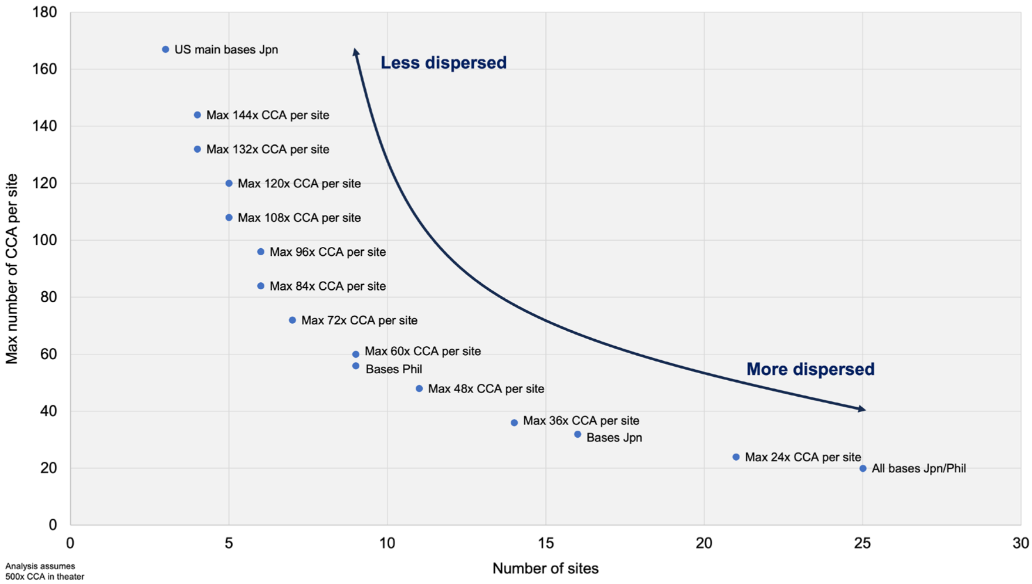
Notes: Table lists one-way distances from operating site to Tainan Airport (Military Grid Reference System: 51QTF1364441269). Entering Taiwanese airspace is not equivalent to reaching Tainan because CCAs flying from Japan and the Philippines would first enter Taiwanese airspace and then reach Tainan. Sortie rates apply to 24-hour period. Loiter hours apply to one-sortie period. Combat radius of 750 nm is unrefueled.

The analysis combined the selected sites into 15 prospective basing configurations with varying levels of dispersion (Figure 3). The analysis crafted the configurations by specifying either the site locations (four configurations) or the maximum CCA inventories per site (11 configurations).[18] In the resulting setup, CCA dispersion is manifested through more sites and fewer CCAs per site.[19]

18 Each "max inventory" configuration increases by 12 aircraft to reflect the notional size of a squadron. Congressional Budget Office, *The U.S. Military's Force Structure: A Primer, 2021 Update*, May 2021, 79, https://www.cbo.gov/publication/57088.

19 In basing configurations with specified locations, the 500 CCAs were allocated evenly across the pertinent sites. In configurations with specified maximum inventories, the 500 CCAs were allocated to whichever sites produced the best results according to optimization analysis. In the least dispersed configuration, three sites operate 166 or 167 CCAs apiece. Although a main base might struggle to operate such a large CCA inventory alongside manned aircraft, the configuration is possible based on historical precedent and potential future choices by planners. (See Department of Defense [DoD], *Conduct of the Persian Gulf War, Final Report to Congress*, April 1992, 142–143, https://apps.dtic.mil/sti/pdfs/ADA249270.pdf). In the most dispersed configuration, 25 sites operate 20 CCAs apiece. The various "max inventory" configurations include inventories falling between the two extremes. Although future commanders might desire more dispersion than the analysis's most dispersed configuration, the options conform with what leading studies have considered. For example, Hamilton and Ochmanek illustrate 300 aircraft dispersed across 20 launch and recovery locations. The resulting dispersion of 15 aircraft per site is not much smaller than what the analysis considers, even though they studied attritable aircraft operating from more austere locations than CCAs would. 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), 19–21, https://www.rand.org/content/dam/rand/pubs/research_reports/RR4400/RR4407/RAND_RR4407.pdf.

FIGURE 3: 15 BASING CONFIGURATIONS WITH VARYING DISPERSION



Source: CSBA analysis.

Notes: Analysis assumes inventory of 500 CCAs in theater.

The analysis did not attempt to identify and evaluate every potential operating site satisfying the search criteria, a goal of other studies.[20] Rather, it sought only to identify enough sites to craft CCA basing configurations featuring illustrative variation in dispersion. In short, the analysis focused strictly on basing dispersion, not individual site suitability.[21]

The different basing configurations would require different supporting infrastructure and logistics. The resulting impacts on CCA sortie generation defy easy prediction. Comparing U.S. main bases with other sites illustrates the point.

On the one hand, a U.S. 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.[22] These capabilities would have to be distributed outward in dispersed configurations, increasing the risk of disruption and delayed sorties. As a RAND study concluded about basing dispersion, "Regardless of the concept it uses, the Air Force will have to trade efficiency for survivability in a high-end fight."[23]

20 Moer et al., "Contested Agile Combat Employment."

21 That said, the number of operating sites considered by the analysis (25) did not differ much from what U.S. planners have considered in real-world contingency planning. *GWAPS,* vol. 3, 36–37.

22 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.

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

On the other hand, a U.S. 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 while also denying China the ability to concentrate offensive fires on a small handful of main bases.

CHAPTER 2

Sortie Generation Model

The analysis started with Stillion and Orletsky's basic sortie-rate model.[24] This type of model appears regularly in unclassified research.[25] The model was adjusted to include both loiter flight time and an associated threat proximity penalty, both of which were derived using a modified Raymer equation.[26] This adjustment produced two notable features supporting the research objectives.

First, the adjustment enabled the varying of loiter time to illustrate different CCA mission profiles. Estimating the sortie rate without considering loiter time would neglect a potentially important aspect of future CCA employment.

Second, the adjustment reduced the sortie rate of operating sites closer to Taiwan. This threat proximity penalty was added to reflect the greater challenges to ground survivability and sustainment associated with launching CCAs from sites closer to Chinese combat power. The penalty may strike some readers as counterintuitive because shorter flight distances typically yield higher sortie rates.[27] The model diverges from this standard approach to avoid simply rewarding sites for being closer to the target (Figure 4). By including a threat proximity penalty, the analysis incorporates enemy resistance despite excluding blue-on-red force exchange calculations.

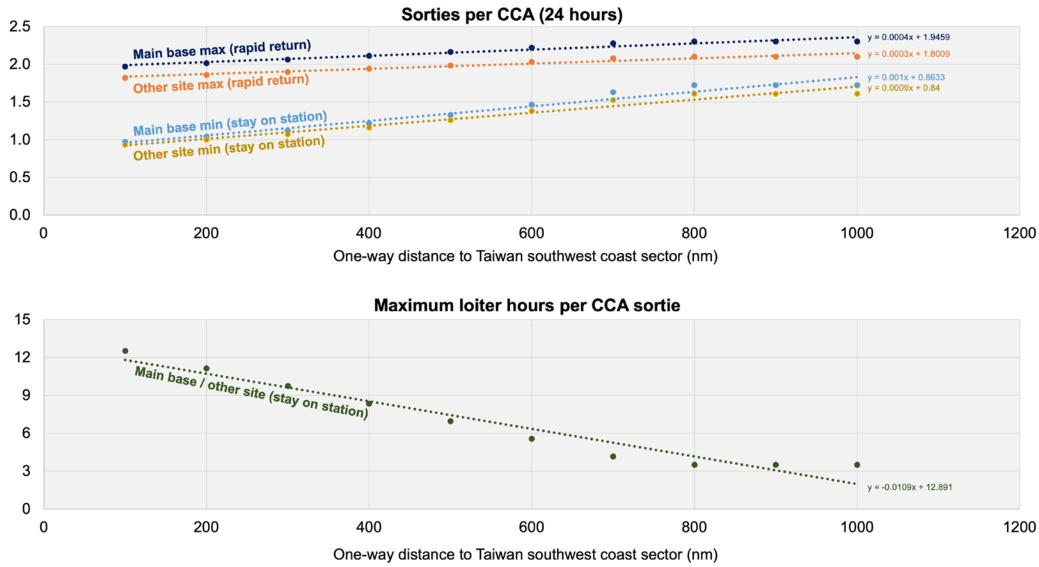
24 John Stillion and David T. Orletsky, *Airbase Vulnerability to Conventional Cruise-Missile and Ballistic-Missile Attacks: Technology, Scenarios, and U.S. Air Force Responses* (Santa Monica, CA: RAND Corporation, 1999), 81–84, https://www.rand.org/pubs/monograph_reports/MR1028.html.

25 Eric Stephen Gons, *Access Challenges and Implications for Airpower in the Western Pacific* (Santa Monica, CA: RAND Corporation, 2011), https://www.rand.org/pubs/rgs_dissertations/RGSD267.html; Eric Heginbotham et al., *The U.S.-China Military Scorecard: Forces, Geography, and the Evolving Balance of Power, 1996–2017* (Santa Monica, CA: RAND Corporation, 2015), https://www.rand.org/pubs/research_reports/RR392.html; and Toshi Yoshihara, Jack Bianchi, and Casey Nicastro, *Focused Force: China's Military Challenge and Australia's Response* (Washington, DC: CSBA, January 2025), https://csbaonline.org/research/publications/focused-force-chinas-military-challenge-and-australias-response.

26 Daniel P. Raymer, "Approximate Method of Deriving Loiter Time from Range," *Journal of Aircraft* 41, no. 4, July–August 2004, 938–940.

27 Heginbotham et al., *The U.S.–China Military Scorecard*, 80.

FIGURE 4: EFFECT OF OPERATING SITE DISTANCE TO TAIWAN ON SORTIE RATE AND LOITER HOURS



Source: CSBA analysis.

Model and Assumptions

$$\text{Sortie rate} = \frac{\text{24 hours}}{\text{TFT + LFT + TGT + MTP}}$$

TFT: Transit flight time. Equals $\frac{2d}{s}$, where d is one-way distance in nm and s is average cruise speed in knots (kts). The analysis assumed a CCA average cruise speed of 500 kts. The Air Force's September 2023 request for information about CCA engine options suggested a transonic maximum speed.[28] One of the aircraft designs selected as an initial CCA finalist, the Anduril Fury, reportedly features a top speed around 630 kts.[29] Assuming cruise speed equals 80–85 percent of top speed, a rule of thumb in commercial aviation, an average cruise speed of 500 kts was a reasonable assumption.[30]

LFT: Loiter flight time. Equals 1.16(12 - 3TFT). Adapted from Raymer's loiter time equation but tailored to prospective CCA design and employment. This LFT equation does not apply to other aircraft because it was specifically estimated for notional CCA performance.

28 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.

29 Jospeh Trevithick and Tyler Rogoway, "The Rise of Fury," *The War Zone*, September 11, 2023, https://www.twz.com/the-rise-of-fury.

30 Stratos, "Understanding Cruise Speed," n.d., https://www.stratosjets.com/blog/cruise-speed/.

The analysis assumed a CCA maximum combat radius of 750 nm when applying Raymer's model.[31] According to Air Force officials, the initial tranche of CCAs will feature a range "relatively the same as our current fighter fleet [and potentially] a little bit longer."[32] The F-35A has a combat radius of over 590 nm with internal fuel and over 825 nm with external fuel.[33] Given this context, 750 nm was a reasonable assumption that aligned with estimates in leading studies.[34]

TGT: Turnaround ground time. This is the period between sorties when a CCA performs routine preparatory tasks such as refueling and updating mission autonomy software and mission plans. The analysis assumed a constant of two hours, which is less than Stillion and Orletsky's assumption of three hours due to differences in ground support operations for CCAs versus manned aircraft.[35] Some experts have suggested CCA turnaround time could total less than 30 minutes, so the analysis's assumption may be too conservative.[36] Assuming a shorter turnaround time would not, however, change Chapter 3's results.[37]

MTP: Maintenance ground time and threat proximity penalty.[38] Equals $b + 0.68(TFT + LFT)$, where b is one hour if the site is a U.S. main base and two hours otherwise, with these maintenance constants increased according to a flight time variable that, in this operationalization, also functions as a threat proximity penalty.[39] The penalty suppresses the sortie rates of sites closer to Taiwan. Main bases carry a smaller time value to reflect their likely sortie-generation advantage as a result of having better ground support capabilities. U.S. main bases also suffer a threat proximity penalty, however, which can cut against that advantage.

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31 The analysis treated the maximum combat radius as a constant and did not vary it based on CCA mission profiles or notional payloads.

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

33 Lockheed Martin, "F-35 Lightning II Program Status and Fast Facts," April 1, 2020, 2, https://www.lockheedmartin.com/content/dam/lockheed-martin/aero/documents/F-35/FG19-24749_004%20F35FastFacts4_2020.pdf; and Brian W. Everstine, "Lockheed Looking at Extending the F-35's Range, Weapons Suite," *Air & Space Forces Magazine*, June 17, 2019, https://www.airandspaceforces.com/lockheed-looking-at-extending-the-f-35s-range-weapons-suite/.

34 Gunzinger with Stutzriem and Sweetman, *Need for Collaborative Combat Aircraft*, 22.

35 Relative to Stillion and Orletsky's manned fighter estimate of three hours, a CCA has no pilot to debrief (save 15 minutes), fewer munitions to rearm (save portion of 50 minutes), and a potentially condensed preflight inspection with no pilot (save portion of 15 minutes). Stillion and Orletsky, *Airbase Vulnerability*, 83; and Daniel V. Hackman and Dennis C. Dietz, "Analytical Modeling of Aircraft Sortie Generation with Concurrent Maintenance and General Service Times," *Military Operations Research* 3, no. 3, 1997, 63.

36 Penney, Glojek, and Jensen, "Ready to Fight All Night," at 34:50 and 35:50.

37 Because the analysis treated turnaround time as a constant, changing it would alter the values, but not the ordering, of the sortie generation results by basing configuration.

38 This term comes from Stillion and Orletsky's maintenance time equation but was modified by adding loiter time.

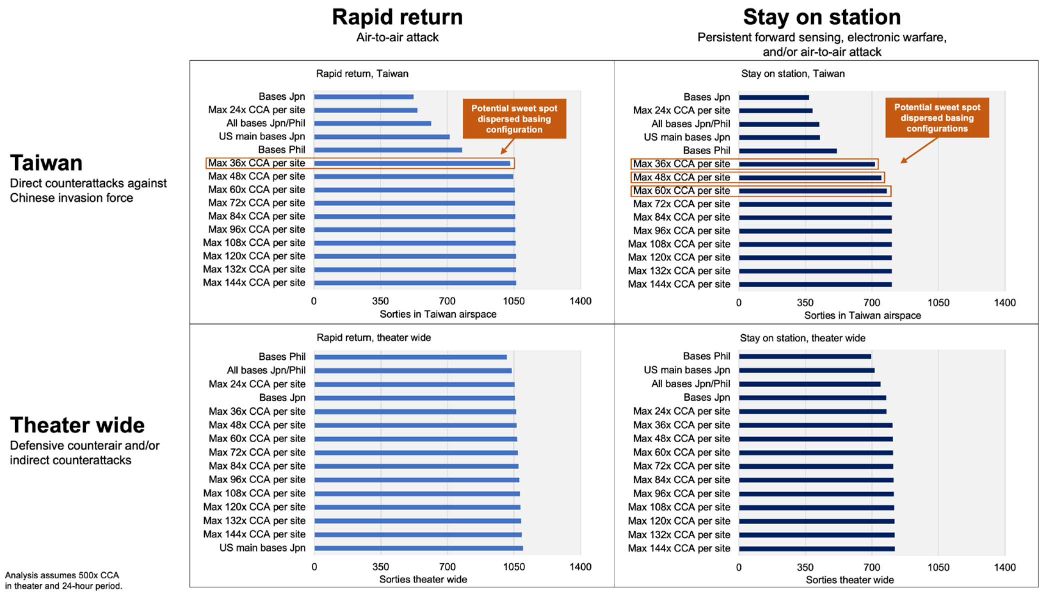
39 The inclusion of a threat proximity penalty precluded exploring different parameters for variable maintenance time. It seems likely that planners would defer CCA maintenance as much as possible to maximize sortie generation during a conflict. Penney, Glojek, and Jensen, "Ready to Fight All Night," at 27:06. On modeling sortie generation with and without deferred maintenance, see Joshua M. Epstein, *Measuring Military Power: The Soviet Air Threat to Europe* (Princeton, NJ: Princeton University Press, 1984), 210–224.

CHAPTER 3

Sortie Results: Implications for Combat Potential, Sustainment, and Basing

The analysis's results suggest the CCA fleet's combat potential, logistical demands, and basing configuration could look very different depending on choices made about employment. Figure 5 depicts how sortie generation varies based on CCA mission profile, CAP geographic emphasis, and basing dispersion. Three insights emerge from the outcomes.

FIGURE 5: SORTIES GENERATED IN 15 BASING CONFIGURATIONS



Source: CSBA analysis.[40]

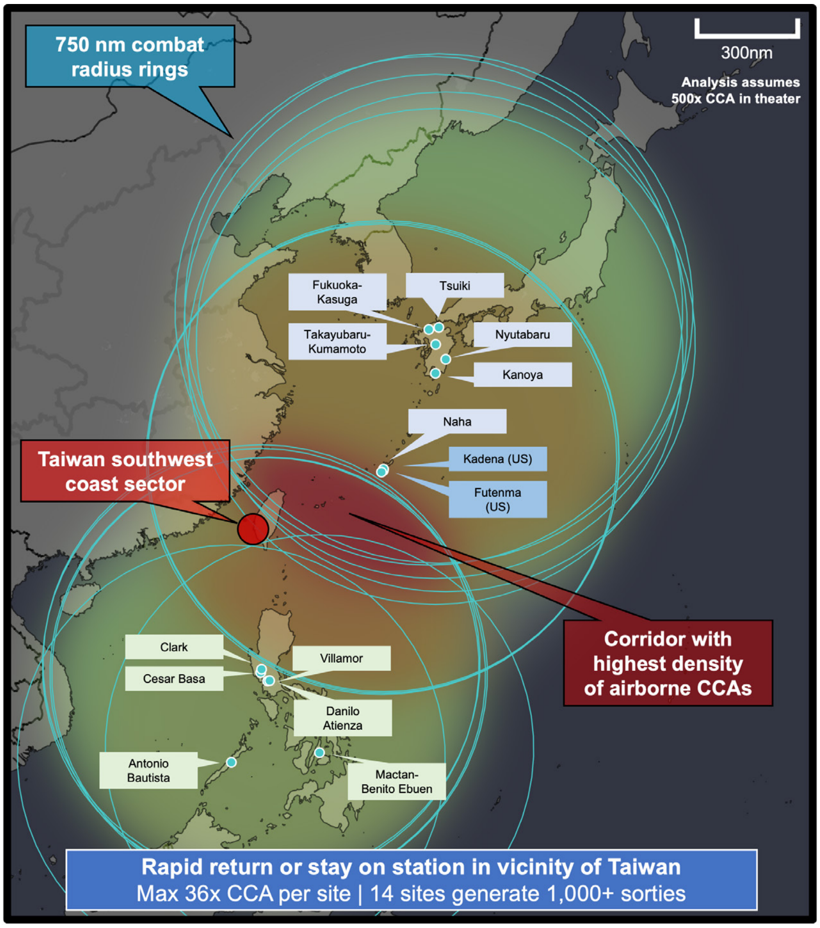
Notes: Analysis assumes inventory of 500 CCAs in theater.

First, CCA employment creates different combat potential. Rapid return produces roughly 25 percent more sorties than stay on station. This difference occurs because rapid return features shorter flight times, which increases sortie rates. The difference in sortie generation leads to a variety of operational possibilities.

For example, imagine the opening day of an air campaign in which the 500 CCAs emphasize Taiwan, deploy 36 aircraft (maximum) at basing sites, and attack Chinese aircraft with two missiles per sortie. Under these conditions (and leaving aside combat losses), a CCA fleet conducting rapid return could launch over 2,000 missiles in the first 24 hours. Due to theater geometry, the CCA fleet in this scenario could generate the densest missile attacks in the air corridor running tangent to northeastern Taiwan (Figure 6).

40 For the four basing configurations not involving optimization analysis (all bases Jpn/Phil, bases Jpn, bases Phil, and US main bases Jpn), the operating sites and CCA inventories per site remained fixed across the mission profile/geography combinations. For the 11 remaining configurations involving optimization, the sites and inventories varied depending on the mission profile/geography combination. Thus, Figure 5 reports the results of 44 optimization iterations (11 configurations x 4 combinations = 44 iterations). Optimization constraints included (a) theater inventory of 500 CCAs and (b) site inventory limit (e.g. max 36x CCA). Optimization performed using Excel Solver Simplex LP (linear) method.

FIGURE 6: CCA AIRBORNE DENSITY IN TAIWAN SCENARIO



Source: CSBA analysis using QGIS.

Notes: Analysis assumes inventory of 500 CCAs in theater and unrefueled combat radius of 750nm. The 14 optimal basing sites (under 36 CCAs per site) are the same for rapid return and stay on station. This is not necessarily true for other basing configurations.

In contrast, a CCA fleet practicing stay on station could launch fewer than 1,500 missiles under the same conditions. Stay on station CCAs would perform functions other than missile launches, so that metric does not capture their full value. The point here is simply to illustrate how mission profile could affect fleetwide firepower. If planners deemed the stay on station missile output insufficient but still viewed that mission profile as advantageous, then they would have to generate more missile launches using manned aircraft or other platforms.

Second, CCA employment entails different logistical demands. Because rapid return involves more sorties than stay on station, it also requires intensified sustainment to support the higher tempo. Fuel offers an instructive example.

Assume a CCA carries 4,000 pounds (lbs) of fuel, the amount reportedly needed by the Model 437 loyal wingman prototype developed by Northrop Grumman-owned Scaled Composites.[41] Under the conditions stipulated above (Taiwan, 36 CCAs per site), 500 CCAs conducting rapid return would consume up to 4.1 million lbs of fuel in a conflict's first 24 hours. In contrast, a fleet performing stay on station would consume closer to 2.9 million lbs. Rapid return's higher consumption equals the combined bulk fuel transport capacity of nearly 100 C-130s, with stay on station's consumption closer to 70 C-130s.[42] These requirements obviously represent different logistical burdens.

Third, CCA employment drives different ideal basing laydowns. Across all CCA employment options, less dispersed configurations produce more sorties. This pattern results from packing many CCAs into either U.S. main bases (which have an assumed ground time advantage) or sites with optimal locations vis-à-vis Taiwan (neither too close to suffer a threat proximity penalty nor too far to suffer a flight time disadvantage). The inverse relationship between basing dispersion and sortie production reflects the likely tradeoff wherein dispersion complicates Chinese targeting but sacrifices some sortie throughput due to weaker ground support, on average, across basing sites.

Within this pattern, though, there are potential sweet spot dispersed basing configurations for Taiwan, most notably 36 CCAs per site. These configurations appear in Figure 5 as knees in the curve where an incremental decrease in basing dispersion yields a disproportionate increase in sorties. Under rapid return and stay on station, decreasing dispersion from 24 CCAs per site to 36 CCAs per site increases Taiwan sorties by 85–90 percent. This result comes from loading more CCAs into sites 450 nm to 850 nm from Taiwan, an ideal sortie-producing range under the analysis's assumptions, while basing fewer CCAs at sites over 900 nm from Taiwan. Further decreasing dispersion from 36 CCAs per site to 48 CCAs (or more) per site would generate more sorties, but these gains appear to be diminishing in nature.[43]

If research using higher fidelity models identified similar sweet spot configurations, then the Air Force could craft plans for command and control, sustainment, and other joint functions based on CCA deployments of a standard size (in terms of aircraft per site). This type of standardization is essential to military planning and would be a breakthrough for the CCA program, though planners would surely develop variations on any standard.

41 Steve Trimble, "Northrop Unveils Model 437 UAS for Attritable Market," *Aviation Week*, September 9, 2021, https://aviationweek.com/defense/aircraft-propulsion/northrop-unveils-model-437-uas-attritable-market.

42 Timothy A. Walton and Bryan Clark, *Resilient Aerial Refueling: Safeguarding the U.S. Military's Global Reach* (Washington, DC: Hudson Institute, November 2021), 48, https://s3.amazonaws.com/media.hudson.org/Walton%20Clark_Resilient%20Aerial%20Refueling.pdf. Rapid return's fuel amount (4.1 million lbs) equals around 6 percent of the capacity of a generic maritime tanker enrolled in the Tanker Security Program. Department of Transportation, "Solicitation of Application for the Award of One Tanker Security Program Operating Agreement," *Federal Register* 88, no. 141, July 25, 2023, 47942, https://www.maritime.dot.gov/sites/marad.dot.gov/files/2023-07/TSP%20Federal%20Register%20Notice.7.25.2023_0.pdf.

43 Additionally, deploying more CCAs into fewer sites would both simplify Chinese targeting and consume more ground support capacity also needed by manned aircraft colocated at the sites.

Even if CCA deployment size could be standardized, ideal basing locations would still depend on employment. The 36 CCAs per site configuration illustrates the point. According to optimization analysis for this configuration, rapid return and stay on station in vicinity of Taiwan both maximize sorties using the same set of 14 sites (Figure 6). However, maximizing sorties in theaterwide areas involves different sets of 14 sites. Broadening the geographic emphasis of CCA CAPs encourages more use of sites like Iwakuni that feature higher sortie throughput due to being a U.S. main base and lie further from the Chinese military power concentrated around Taiwan.[44] The best basing locations thus depend on employment choices.

That said, four locations were utilized across all the employment scenarios for 36 CCAs per site: Fukuoka-Kasuga, Takayubaru-Kumamoto, Tsuiki, and Antonio Bautista. These sites reign as the powerhouse sortie producers under the analysis's assumptions. All are located approximately 800 nm from Taiwan, a range that minimizes the threat proximity penalty but involves shorter flight times to Taiwan than more distant sites. Assuming research with higher fidelity models corroborates these findings, the United States ought to prioritize arranging access and sustainment at these four sites that appear highly valuable across CCA employment options.

44 The largest number of sorties generated by one site in the analysis was 385 (Iwakuni in the "U.S. main bases Japan" configuration). During the Gulf War, King Fahd base generated 298 manned aircraft sorties on its peak day (January 17, 1991). Because CCA sorties might be generated faster than Gulf War manned aircraft sorties, particularly if CCA turnaround and maintenance times were shorter, the maximum per-site value of 385 CCA sorties falls in the realm of possibility. *GWAPS,* vol. 5, 1993, 23, 29–30, 376–378.

CHAPTER 4

Beyond Sorties: Combat Losses, Fleet Size, and Quantity–Cost Tradeoffs

The number of CCAs lost in combat would depend in part on how planners employed the aircraft. Prioritizing CAPs in vicinity of Taiwan, for instance, would presumably lead to higher CCA loss rates than emphasizing CAPs in theaterwide areas. For CCAs to remain operationally relevant throughout a conflict, the fleet would have to be large enough to absorb expected losses and still execute required missions.

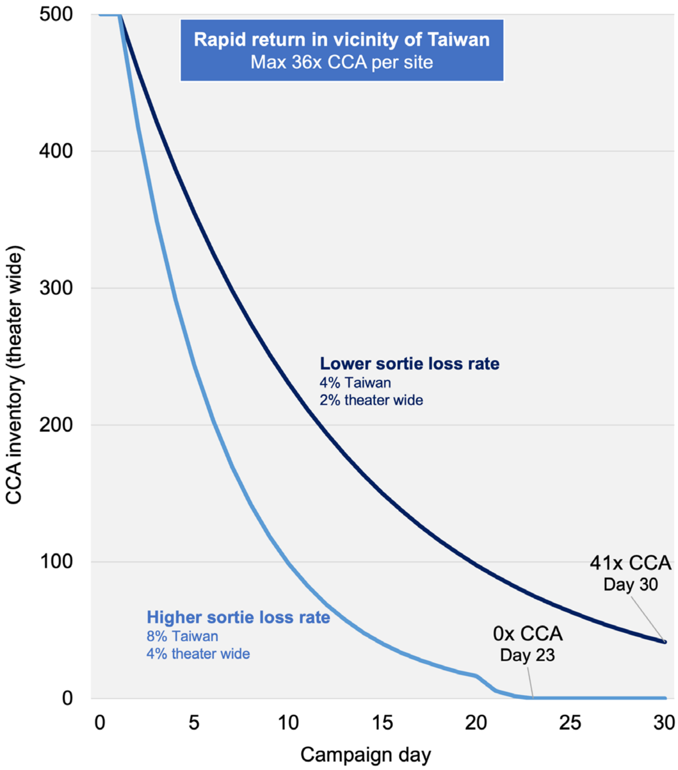
To illustrate the relationship between combat attrition and fleet size, consider an air campaign in which 500 CCAs perform rapid return in vicinity of Taiwan with 36 CCAs (maximum) deployed at each basing site. Assume the sortie loss rate near Taiwan is double the rate in theaterwide areas. Further assume two possibilities for the Taiwan loss rate: under the higher rate, sortie losses equal 8 percent, roughly equal to what U.S. Eighth Air Force bombers suffered in early 1943; under the lower rate, sortie losses equal 4 percent, equal to the Eighth Air Force's improved situation in early 1944.[45]

Under the higher loss rate and based on Chapter 3's sortie modeling, the entire CCA fleet would be destroyed in 23 days (Figure 7). Under the lower rate, only 41 CCAs would remain after 30 days of fighting. Of course, the CCA fleet would fare even worse if sortie loss rates were higher than illustrated here, a real possibility considering China's advancing air warfare capabilities.[46]

45 Williamson Murray, *Strategy for Defeat: The Luftwaffe, 1933–1945* (Maxwell, AL: Air University Press, 1983), 345, https://www.airuniversity.af.edu/Portals/10/AUPress/Books/B_0012_MURRAY_STRATEGY_FOR_DEFEAT.pdf.

46 DoD, *Military and Security Developments Involving the People's Republic of China*, December 2024, 59–63, https://media.defense.gov/2024/Dec/18/2003615520/-1/-1/0/military-and-security-developments-involving-the-peoples-republic-of-china-2024.pdf.

FIGURE 7: ILLUSTRATIVE CCA COMBAT LOSSES IN TAIWAN SCENARIO



Source: CSBA analysis.

Notes: Analysis assumes starting inventory of 500 CCAs in theater.

To avoid running out of CCAs during the campaign, planners would have at least two nonexclusive options: (a) build an attrition reserve (larger quantity) or (b) build more survivable and expensive CCAs (higher cost). Exchanging quantity for cost represents the tradespace for CCA design.

In the larger quantity option, planners could use reserve CCAs to replace lost aircraft. Under the analysis's assumptions, keeping at least 200 CCAs actively in the fight for 30 days—an assumed minimum for operational relevance—would require nearly 800 reserve CCAs. That reserve force would be in addition to the initial inventory of 500 CCAs, meaning the total theaterwide fleet would number at least 1,300 CCAs.

If the United States assigned two thirds of globally available CCAs to an Indo-Pacific contingency, the assumption used in the analysis, then a theaterwide fleet of 1,300 CCAs would imply a total U.S. CCA inventory of nearly 2,000 aircraft. That figure aligns with Air Force statements that its goal of acquiring at least 1,000 CCAs is merely "a reasonable starting point" that could increase twofold or more.[47] Overall, the analysis finds the Air Force's preliminary inventory goal to be entirely reasonable.

In the higher cost option, planners could field more survivable and expensive CCAs that suffered lower attrition by performing better against Chinese threats. Imagine that the theaterwide fleet of 1,300 CCAs (500 primary, 800 reserve) illustrated above consisted of CCAs costing $10 million per aircraft, a procurement price target reportedly emphasized by the Air Force.[48] At that price, the cost for 1,300 CCAs would be $13 billion.

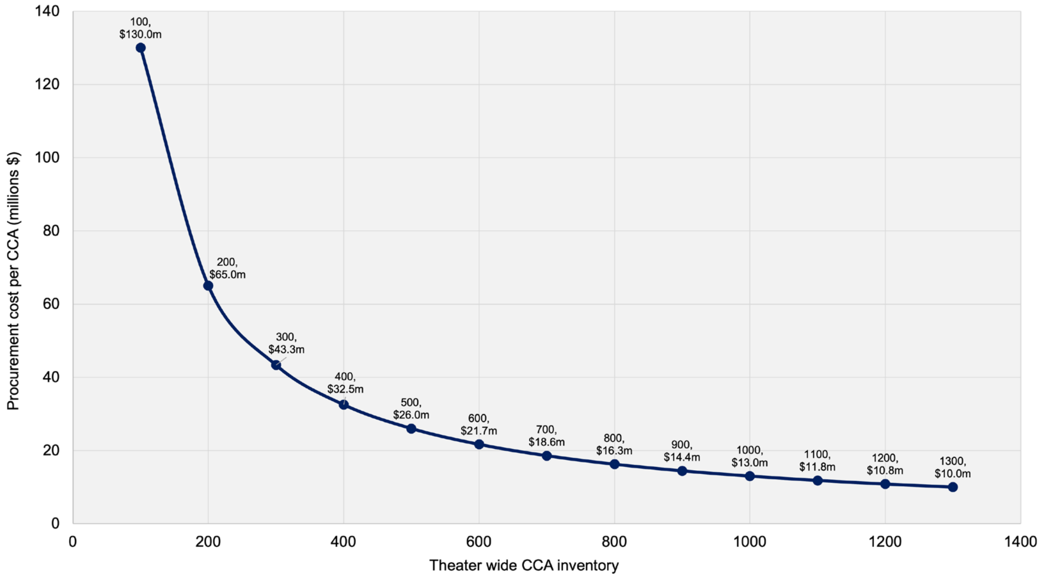
That money could instead be spent to improve CCA survivability so the fleet did not require such a large attrition reserve. The result would be a smaller fleet of more capable CCAs that could hypothetically meet the same performance objective (at least 200 aircraft surviving after 30 combat days) while costing the same amount of money ($13 billion). Because it would be smaller, this more capable CCA fleet might also consume fewer of the ground support resources also needed by manned aircraft.

Figure 8 plots breakeven points for trading quantity and cost under the analysis's assumptions. Each point on the curve represents $13 billion in total procurement spending. These points are breakeven strictly in terms of theaterwide inventory and unit cost, not operational performance. Research using higher fidelity models would be required to determine how the various quantity–cost options would perform in battle against China. The takeaway here is simply that increasing CCA capability might pay for itself if it reduced the required size of the fleet.

47 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/.

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

FIGURE 8: QUANTITY-COST BREAKEVEN POINTS FOR $13 BILLION PROCUREMENT INVESTMENT



Source: CSBA analysis.

Notes: The figure reflects the two starting assumptions discussed in the main text: (a) theaterwide inventory of 1,300 CCAs and (b) CCA procurement unit cost of $10 million.

CHAPTER 5

Conclusion

There is no one-size-fits-all solution to employing and basing CCAs for 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 applications. This emphasis on generality, though initially helpful for expanding the coalition of CCA supporters, has become detrimental to the program. Many smaller details depend on bigger choices about CCA employment and basing, as this report illustrates. If the Air Force continues communicating about these two issues generically, then it risks appearing unserious about the entire CCA endeavor.

The Air Force has no perfect play to make with CCAs, no dominant strategy that guarantees success. Such is the nature of military competition with a powerful and competent adversary like China. Delaying force planning choices makes sense when one believes 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 and basing options appear unlikely to emerge. Meanwhile, conflict with China is distinctly possible in the next decade, and the United States could lose that war, according to authoritative studies.[49]

Given this situation, the Air Force should make the best decisions about CCAs it can, as soon as it can, and communicate them as widely as it can. Making specific choices today, even though they may later prove to be flawed in various ways, beats deferring decisions in search of better answers that may never come. The future U.S. Air Force can prevail without being dealt the 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.

49 National Defense Strategy Commission, *Final Report*, July 2024, 6–7, https://www.rand.org/content/dam/rand/pubs/misc/MSA3057-4/RAND_MSA3057-4.pdf.

LIST OF ACRONYMS

CAP	combat air patrol
CCA	collaborative combat aircraft
CSBA	Center for Strategic and Budgetary Assessments
DoD	U.S. Department of Defense
GWAPS	Gulf War Air Power Survey
LFT	loiter flight time
MTP	maintenance ground time and threat proximity penalty
NGAD	Next Generation Air Dominance
TFT	transit flight time
TGT	turnaround ground time

CSBA

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