



The Mitchell Forum

Collaborative Combat Aircraft Need Data to Train for Combat

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Abstract

"Data are just summaries of thousands of stories—tell a few of those stories to help make the data meaningful."

-Dan and Chip Heath

In the field of machine learning and artificial intelligence, "data" has become a buzzword; it is celebrated as both the New Oil and the New Plutonium. Despite its apparent value, "data" is a word so broad that it lacks meaning without context. The purpose of this Mitchell Forum primer is to offer clarity and to invite discussion about the datasets required to train Collaborative Combat Aircraft (CCA) algorithms for combat.

AI-powered software pilots have the potential to fulfill the U.S. Air Force's quest for affordable tactical airpower capacity; however, the foundational requirement for data to enable air combat autonomy algorithms is not well-understood. This article addresses the Air Force's tactical airpower data management challenge, acknowledges arguments against the importance of data for CCA fielding, and identifies four specific reasons why funding and implementing a deliberate data management plan is crucial to accelerate successful CCA development and fielding. As the U.S. Air Force seeks to fulfill its mission to "Fly, fight, and win... airpower anytime, anywhere," understanding specific data requirements is an early step on the path toward fielding Collaborative Combat Aircraft.

Introduction

This is a story about data, and it started over Syria in the summer of 2016. I had just landed my F-16 after a bizarre seven-hour combat sortie, flying close air support over the northwestern Syrian city of Manbij. My wingman and I had dropped our entire loadout of bombs—most of them within “danger close” distance of our partner Syrian Democratic Forces—while special operations combat controllers described our targets via satellite radios. We had been interrupted during the hottest part of the urban ground battle by a Russian SU-30 Flanker flying within our air combat commitment range. I left my wingman in charge of the close air support mission for a few minutes while I intercepted the Flanker pilot to keep him from interfering. This was not a boring sortie—we were flying supersonic fighter jets loaded up with live weapons, operating a few miles above the same bad guys who had recently burned a captured fighter pilot alive in a cage, dropping bombs into an urban battle, and intercepting an adversarial fighter jet that we weren’t authorized to shoot down unless he committed a hostile act. The lines get blurry in that world. It seemed unwise

to shoot down a Russian jet and start World War III, so I used snippets of data and a series of contextual questions to make decisions during the intercept. Had the Russian locked onto me with his fire control radar? Had he employed electronic attack programs to degrade my sensors? Was he maneuvering aggressively toward me? Fortunately, humans are capable of sensing and fusing the elements of a complex situation, and I had enough information to rock my wings like a gentleman at the Flanker pilot as he turned away from our engagement. We got back to supporting the fight over Manbij, employed the rest of our weapons, and flew home high and fast through the central Syria “Superpower Lane.” As the U.S. Air Force builds AI-powered robot wingmen, there looms a foundational question: What data will the Air Force use to train collaborative combat aircraft to handle the complex scenarios human pilots solve daily in combat?

What is Data?

The word “data” refers to a collection of facts, observations, measurements, or any other information that can be stored and analyzed to gain insights, draw conclusions, or



The XQ-58 Valkyrie is an uncrewed aircraft that the U.S. Air Force is flying at Eglin AFB to develop and test autonomy software.
Source: [Air Force Research Laboratory Photo](#)



The X-62 is an invaluable live-fly autonomy testbed. The Air Force plans to modify additional F-16s for autonomy testing in Project VENOM.

Source: [U.S. Air Force Photo](#)

make decisions. In the context of autonomous vehicle development, data includes geographic information system overlay maps and millions of LIDAR voxels (3D pixels that represent the real world) that build the foundation for the machine learning algorithms driverless cars use to perceive their environment and make decisions. For those working to transform the concept of uncrewed collaborative combat aircraft (CCA) into reality, the word “data” is still ambiguous. The purpose of this article is to offer clarity and to invite discussion about the datasets required to train robot wingmen’s algorithms for combat.

The Air Force’s Data Management Challenge

Can CCA developers use existing datasets to train algorithms to fight alongside a manned fighter aircraft, and leverage decades of data collected from high-end test and training events on advanced flying ranges and in combat simulators? The answer is no. There are no datasets that represent complex air combat scenarios. This unfortunate lack of airpower-related data is a huge barrier to rapid CCA fielding, yet still, the U.S. Air Force has *no data management plan for tactical airpower*.

The Secretary of the Air Force’s Chief Data & Artificial Intelligence Office has created a “Data Fabric” that provides data access, management, and data analytics

tools through six Big Data Platforms. The Air Force’s Big Data Platforms pull data from over 300 authoritative sources and provide valuable insights into domains such as cyber, space, intelligence, logistics & sustainment, and administrative business intelligence. However, the Air Force ironically lacks data management investment in the tactical *air* domain.

The Fly, Fight, and Win crowd—the operators and warfighters—are still stuck in the digital dark ages of laminated mission planning maps, dry-erase marker drawings on briefing whiteboards, and the “oral histories around the tribal campfire” model of debriefing tactical missions. At the grassroots level, with notable Air Combat Command general officer support, one operational test squadron is driving progress toward tactical airpower data collection. The Crowd Sourced Flight Data program includes an “aftermarket” improved data recording capability installed on Air Force operational test F-35s and a few combat squadrons’ F-35s. The program also includes a Knowledge Management data storage system that allows local post-flight data analysis; however, the current lack of classified IT infrastructure prevents data consolidation and sharing among flying units. These grassroots efforts are a commendable starting point, but the critical remaining data management themes of labeling, visibility, accessibility, analytics

and usage, and overall value generation remain as work yet to be undertaken. For this reason, CCA program managers must figure out their data requirements from scratch.

Counterarguments: Is a Data Management Plan Really Required for CCA?_____

Before we can think through CCA data requirements, we must first consider the three main arguments against the need for data to train air autonomy algorithms.

Counterargument #1: We have not needed a data management plan during early AI pilot simulation work. Early approaches to developing airborne autonomy algorithms have not used supervised machine learning and associated large, labeled datasets. Competitions like DARPA's Alpha Dogfight saw success using rules-based approaches developed by pilots (subject matter experts), followed by refining the algorithms using rewards and other data-sparse reinforcement learning techniques.

Response #1: It's true that a data management plan to bridge the gap between simulation and the real world was not needed during early air combat autonomy work. However, that approach works only *if* the autonomy agent is fed perfect "state information" about its adversary and simulation environment. When the autonomy software agents start to fly in the real world, they will require sensors to gather state information about their environment, including the location and identification of adversary aircraft. Sensors and identification problem sets will require labeled data and supervised machine learning to build accurate sensor reference libraries—just like autonomous cars need large, labeled datasets to train their perception of the driving environment.

Counterargument #2: Large volumes of airspace make airborne autonomy relatively easy. One Air Force analyst at the Pentagon scoffed in response to our research questions about CCA data requirements: "It's easier in the air than on



DARPA's Alpha Dogfight competition winner used reinforcement learning techniques to refine the algorithm that defeated a human fighter pilot in a simulation environment.

Source: Screen capture from [DARPA video](#)



CCA development and the data to train CCA algorithms are integral to the success of the Next Generation Air Dominance (NGAD) program, the U.S. Air Force's next fighter aircraft family of systems.

Source: Mike Tsukamoto/Air & Space Forces Magazine and U.S. Air Force photos

the roads... big sky theory dude!" A common argument is that the air environment is less complex than roadways because there are no sidewalks in the sky, and therefore the Air Force will require less effort and fewer complex datasets to train autonomous pilots than is required to field driverless cars.

Response #2: This argument might hold true if the air domain was not contested by adversaries. Furthermore, dynamic combat flying is not the same as commercial flight. In the case of autonomous driving, road hazards strain driverless car algorithms, and the industry has only made progress by spending billions of dollars collecting millions of data points to train their autonomy software over the past forty years. It is naïve to think that the autonomy challenges of a highly contested air combat environment in a Taiwan Straits conflict will be more easily overcome than autonomous vehicle challenges on North American roads.

Counterargument #3: Fast fielding is more important than developing a truly autonomous teammate; the pilots will figure it out. CCA robot wingmen do not need a high level of autonomy at first. The Air Force can accept a basic level of aviate-navigate automation and increase pilot workload to accelerate fielding.

Response #3: This is the most convincing argument against the need for a deliberate data management plan for CCA

fielding—if you are not a pilot. Today's human aircrew are already max-performing in the cockpit. Additional cognitive demands and heads-down time controlling robot wingmen with an after-market tablet interface will ruin operators' fragile trust in uncrewed CCA systems, which could in turn delay adoption by years or decades. The argument for significantly increasing human pilot workload to closely control CCA wingmen is extremely short-sighted.

What Data Will Collaborative Combat Aircraft Need to Prepare for Combat? _____

Successful development and fielding of CCA will require a deliberate data management plan for the following four reasons:

- 1. Data for verification and validation (V&V) of autonomy software.** In the new paradigm of iterative CCA software development, many test professionals have observed that software agents are always learning and never done with their training. Rapid software iteration demands an equally rapid cycle of testing and data collection to verify acceptable performance and make fielding recommendations. An additional challenge for testers charged with V&V of software pilots is the lack of explainability associated with many AI algorithms, including deep learning

approaches. In contrast to human pilots who can verbally describe their flying errors in the flight debrief, software code often lacks the ability to explain its outputs and actions. Not only will test professionals need to instrument the autonomous aircraft to gather control and performance data, but they will also need to gather data about the software agent's perception, decision-making (if possible, within current black box software constraints), and execution. *CCA programs will require data to understand software nuances and to provide assessments of trustworthiness based on the autonomy agents' performance.*

2. **Data to improve the simulation environment.** Live-fly testing is expensive and unforgiving. High-fidelity simulation, with practice scenarios running at speeds faster than real-time, is a foundational requirement for developing autonomous systems—especially for reinforcement learning. Without a high-fidelity simulation environment, autonomous agents will appear to perform well and be ready for live-fly testing. However, in the physical world, they could quickly betray their models as brittle and fail when they inevitably fly in real-world conditions they never saw in simulation. Reinforcement learning will produce results only as good as the simulation environment. Success will require accurate software models of aircraft, adversaries, sensors, and weapons. *CCA programs will need an automated cycle to take real-world data and feed it into the simulation environment for continuous refinement.*
3. **Data for daily testing, tactics development, and training.** This is intuitive for military aviation professionals, but it will require a major shift toward all-digital operations to train software pilots. Human pilots mission plan,

brief, and execute tactical missions, then debrief as they train for constant improvement. However, software agent pilots cannot process the whiteboard mission briefings or verbal debriefs used by human aircrew. *CCA autonomy agents will require a digital, data-driven test-tactics-training mission cycle that scales to share lessons-learned across the CCA development enterprise.*

4. **Data to refine sensor reference libraries.** The transition from simulation to the physical world is tough. In a simulation, autonomous CCA agents can cheat—the simulator is typically “fully observable,” giving the agent details about their environment with perfect state information. In contrast, the physical world is “partially observable” and demands that the aircraft's sensors perceive the environment—threats, friendlies, terrain, weather, and other conditions that impact airborne decision-making. This sensor perception of the partially observable environment will always be imperfect and incomplete. *CCA sensor libraries will require data to improve how accurately the software brain (or inference engine) interprets the world around it.*

So What?

The U.S. Air Force needs collaborative combat aircraft to gain air superiority in potential future conflict with China, our pacing threat. CCA algorithms need the kinds of data highlighted here to prepare for real-world combat. To increase the probability of successful fielding, the growing community of CCA stakeholders must continue to identify specific data requirements and collaborate to create a deliberate, funded data management plan that complements and reinforces ongoing CCA development efforts. ✪

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