Lessons Learned from Aviators to Support Advanced Teaming and Training

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ABSTRACT

Future concepts for mission execution and platform capabilities on programs such as Future Vertical Lift (FVL) generate expectations for pilot skills to manage vast data streams while interacting with autonomous assets. As a result, there are several considerations for training pilots in preparation for advanced teaming tasking including communication, trust, and workload balance (Anania, Atkinson, Frick, Pharmer, & Killilea, 2020). From a workload perspective, training that provides pilots with an opportunity to learn how to deal effectively with dense data volumes and to coordinate with autonomous systems and unmanned assets will be critical to successful operations.

As part of an on-going effort to develop training technologies and tools to assist with workload evaluation and technology mastery, a series of interviews were conducted with pilots from existing Department of Defense (DoD) platforms. The goal of these interviews was to establish a baseline understanding of the types of automation currently available to pilots. These interactions provided an opportunity to identify challenges associated with employing automation during operations, and to utilize pilot insights to optimize training processes associated with the adoption of new technologies. This paper reviews the themes generated from these interviews and provides insight into the types of emerging and innovative technologies that might facilitate the workload-management training needed to produce proficient future pilots [e.g., how pilot training, alongside Artificial Intelligence (AI) systems, can shape and improve AI systems themselves]. Findings address existing levels of automation and the current challenges with automation, future perceptions of and barriers to the adoption of automation, factors impacting operator trust of automated systems and AI, and methods to improve training (technology and pipeline). Discussions focus on the design of a learning management system that integrates human performance modeling and simulation-based training to offer near-real-time iterative training to improve: human-AI teaming, situational awareness, technology understanding, and pilot workload management.

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INTRODUCTION

Major technology breakthroughs and implementations emerging today, coupled with rapid improvements such as machine learning, result in technology availability at a pace that far surpasses the deployment of training programs. As a result, there is an increasing gap in user understanding, application, and management of these capabilities. While advanced artificial intelligence (AI) and sensor fusion technologies are reaching maturity for incorporation into aviation systems, several challenges for employment remain. First, there is a lack of training on these technologies. Additionally, obstacles exist that are barriers for adoption. For example, there is often an overarching distrust with automation technologies and a general lack of knowledge of how AI and data fusion technologies work or should be expected to behave. Finally, most consumers of these technologies do not consider that trust is a two-way street (i.e., human to system and system to human). Despite these challenges, machine learning, neuromorphic computing, and physiological monitoring technologies, place us on the cusp of an advanced teaming revolution that can give our defense branches increased combat power and effectiveness. However, if we expect to have end users exploit these technologies to their full potential, training must evolve as quickly as the technologies themselves. Training needs to be developed today to support these technologies tomorrow.

TRAINING IMPLICATIONS OF TECHNOLOGY EVOLUTION

To understand how to best support aviators in their training on future technologies, we interviewed over two dozen Navy and Marine pilots of manned and unmanned systems, as well as two retired Intelligence, Surveillance, Reconnaissance (ISR) Tactical Controller (ITC) personnel. Interviews revolved around technologies, automation, the needs of future-facing programs such as Future Vertical Lift (FVL), supporting Unmanned Aircraft System (UAS) management with technologies, advanced teaming, and training. Interviews established a baseline understanding of the general types of anticipated technologies to include automation, which is currently available in limited form in some but not all cockpits. Additionally, subject matter expert (SME) interviews clarified the types and frequency of training desired to assist with understanding how to best use these future-facing technologies. Pilot interviewees had a range of platform experience ranging from rotorcraft, fixed wing, and unmanned. Flight hours for each pilot ranged from 500-3,500 flight hours; the majority of SMEs reported over 1,000 hours of flight experience. Background platform experience included flying a variety of current fixed wing and rotorcraft manned platforms, as well as a variety of UAS representing small, medium, and large unmanned platforms.

Interviews

Interviews were conducted via Microsoft Teams and included at least two interviewers and a single interviewee; due to availability, one interview session involved three interviewees. Each interview session lasted approximately 30 minutes covering a variety of topics including automation technologies, training, lessons learned, and technology reliability. During discussions surrounding automation technologies, interviewees were asked to provide examples

of technology and trust in automation, as well as general capability levels and perceived limitations. Training questions included the discussion of introducing new capabilities within a simulator, as well as "adventure training" or the introduction of a new system to a pilot or aircrew during a live operations flight that results in unstructured exploration of the capabilities. Additional training topics addressed during interviews included standard training practices. For example, training of new systems may occur via a slide presentation such as Microsoft PowerPoint followed by an introduction to an operational system in live flight. Alternatively, new technologies may be introduced through the implementation of new training solutions or capabilities. Discussions addressed these variations in training approaches, and how pilots would like to see training around new or emerging technologies improve in the future. Finally, interviewees provided feedback on experiences associated with technology reliability, such as instances when technologies worked and did not work as expected in both professional and personal environments.

These interviews helped to form a baseline understanding of the various types of technologies that are currently available to aviators, how they use these technologies, and how they train to use automation along with new technologies in general. Additionally, several probing questions were geared toward understanding how pilots gain and lose trust with automation systems, as well as how automation reduces workload. While these general themes remained constant from interview to interview, specific questions evolved over time based on interview findings and the interviewee's background. For example, emphasis was given to questions involving training if a pilot had an instructor background, or detailed responses were sought to focus on the differences in automation between various aircraft and how pilots transitioned from older, less automated aircraft to newer aircraft with more advanced automation if a pilot had experience with multiple aircraft variants.

Findings

Results from these interviews can be categorized into seven key findings associated with technologies, training, and the gaps between the two.

Finding 1 - There is very little advanced teaming today
Advanced teaming – defined herein as human-autonomy teaming or manned-unmanned teaming – incorporates a partnership between manned and unmanned aircraft. Five levels of human and system interoperability, known as a Level of Interoperability (LOI), have been established to organize and understand requirements needed to support advance teaming (Marques, 2012). The LOI itself does not directly translate to the amount of autonomy the system contains, but rather the level of expected interaction the human operator(s) has with the system (Durst & Gray, 2014). Programs such as FVL expect to have a Level of Interoperability (LOI) of 4 or higher. An LOI 4 is considered control of an unmanned asset (flight and sensor payload) with the exception of takeoff and landing by a manned pilot (from U.S. Army Unmanned Aircraft Systems Roadmap 2010-2035). Today, however, most technologies are at best an LOI 2; this level indicates that a pilot is authorized to receive and display imagery and data directly from an unmanned aircraft without filtering or processing. This delta between expectation and reality means a lot of new technologies including automation, advanced sensors, and interfaces need to be developed before we reach current goals.

Finding 2 - There exists a large automation divide among today's platforms
Interviews revealed that military aviators flying vertical lift aircraft (including a variety of rotorcraft) have limited automation in the cockpit and very little experience with AI. When automation is in the cockpit of vertical lift aircraft, interviewees described three systems: an automated flight control system (colloquially referred to as "George"), a threat warning and mitigation system, and a target tracking sensor. Note that a deeper review of these identified systems reveal that threat warning and target tracking are not necessarily automation defined by a technology used to perform a task with minimal human input, but rather sensor or display systems used to inform operator decision making. That said, some of the more modern platforms do have advanced flight control systems. The V-22 Osprey for instance can fully fly the aircraft from takeoff to landing and can fly precisely in degraded environmental conditions. Interviewees of such advanced platforms stated "Automation is my (technology) copilot." This is in stark contracts to older platforms that have seen limited to no automation adopted, with one interviewee of an older platform joking, "Automation is my (manned) copilot."

Finding 3 - Pilots have some familiarization with automation in the cockpit; some experiences are good, some not
Feedback from interviewees indicate that early automation had more issues than emerging systems, something that is likely heavily influenced by the maturity and evolution of technology. Of the 11 interviewees who had experience with early automation, all 11 indicated impacts on trust in automation. These interviewees attributed their lack of trust of automation to the fact that these systems proved to be unreliable at times and/or these systems would perform functions that did not always meet the pilots' expectations. These older systems also tended to not provide feedback on why automation functioned a certain way, often discussed as system transparency, further reducing the amount of trust a pilot would have with the system (especially when the system did something seemingly incorrectly to the pilot). Fortunately, interviews also indicated that today's automated systems are much better in that they are more reliable and meet pilot expectations more often. Further, there are typically real-time data streams informing the pilot why the system made a certain decision or performed a certain maneuver, hinting at the application of explainable AI to a certain degree and that it is possible to regain trust in automation based on positive experiences with the automation.

Pilots interviewed appeared to understand that performance of the system depends on the inputs that they enter into the system. Additionally, pilots indicated that the level of trust with the system is directly correlated to whether or not the system behaves as expected – both on an instantaneous basis upon initial transfer of control to the automated system(s), and on an aggregated basis across deployments. Pilots tend to lose trust with the system when the system does not behave as expected. As a result of this lost trust, pilots sometimes quickly retake control when immediate feedback is inconsistent with their expectations. However, trust appears to build with more experience with a given automation system. Oftentimes, pilots learned through increasing exposure to the automation platform that the system did not behave as expected because they did not fully understand the system, how the system works, and the limitations – and benefits - of the system itself. Additionally, pilots are adaptable, learning and trusting automation systems even when the system does not perform as initially expected. This trust typically occurs through continual practice with the system to gain a better understanding of its limitations. Pilot adaptability means that losing trust with an automated system at any given point in time is not a deal breaker and trust can be regained with further training and experience. These findings are important for training pilots to use AI, since the "black box" nature of the AI systems' algorithms often means it's not apparent what the AI is thinking and why the AI chose a particular conclusion. This uncertainty can be frustrating to the end-user, especially when the conclusions are not accurate or misaligned with the mental model of what the end-user was expecting/anticipating. This further enforces the need for improved human-AI teaming, where the AI learns alongside the human over time, to iterate over, and to find the best solution for mission success for both the automation and the end-user.

Unsurprisingly, all interviewees reported wanting the autonomous systems controlling their own craft to have a human-in-the-loop for critical decision making, such as target engagement, threat mitigation, or aircraft maneuvering. The desire for a pilot to be in the loop was likely rooted in previous experience with automation systems that did not perform as expected or were not effective in all conditions. For instance, one pilot explained that when equipment "has a significant number of false positives" in specific environments, individuals will often disable the system to prevent the unnecessary alerts or reactions. Also note that some pilots – typically pilots who had experience with newer, more robust automated systems – were accepting of fully-autonomous *human-on-the-loop* systems in addition to *human-in-the-loop*. This is an important distinction as autonomous systems rapidly mature and advances in AI increase the feasibility of *human-on-the-loop* systems; while traditional *human-in-the-loop* technology require direction, responses, or other close interaction from the human counterpart, *human-on-the-loop* moves the human into a supervisory or decision authority role (e.g., Fischer et al., 2017). However, there is still a level of proficiency and reliability needed in the system before reaching a level of trust for implementation in a live deployment.

Finding 4 - Aviators generally have a skeptical optimism towards more automation
Several interviewees stated that the only way for an aviator to trust a system is through continual training experience with the system until they have high confidence in how the system will perform. Unfortunately, many interviewees suggested this does not happen often. The primary drivers for incorporating in-cockpit automation technologies are to reduce workload, boost pilot efficiency, and improve safety. Pilots are especially interested in automation systems that can help land the aircraft during degraded environmental conditions, such as dust during a ground landing or turbulent winds when landing on a ship. Pilots recognize that these are times when their own skills are significantly challenged by factors outside their control. Additionally, several pilots acknowledged that a heavily automated helicopter (if the automation is consistent and reliable) could provide opportunities to *reduce* the number of crew

members required to fly select mission types. These pilots stated they felt with extensive and effective automation "the co-pilot is bored when not flying and everything is normal since there isn't much to do."

While this seems to identify a path to reduced crew being facilitated by extensive human/AI teaming training, some interviewees expressed concerns. For example, although interviewees expressed an interest in having more automation in the cockpit, pilots were cautious about having additional complexity that could distract from the mission and increase workload. Additionally, interviewees oftentimes felt they must be convinced that the automated system will perform as expected in all conditions before adopting a system. Further, some interviewees (typically from older, less automated platforms) were apprehensive about letting a system take control of the aircraft, with one pilot stating that he "doesn't even like other pilots taking control of the helicopter."

Finding 5 - Aviators value training new technologies in a simulator before using the new technology in an aircraft
The main area for improvements to simulators reported by interviewees involved simulator parity with aircraft in several dimensions. First, the simulators are almost always behind software versions in the aircraft due to the way contracts are handled with the simulator provider and technology vendors. Thus, new software is typically deployed to the aircraft many months (in some cases 6-12 months) before the simulator. This impact of the acquisition process forces pilots to learn new software updates during actual flying. Secondly, simulator hardware lags behind aircraft and new parts to fix broken simulator components or hardware upgrades can take years before they are applied to the simulator. Lastly, simulator parity with aircraft also fell short for both flight feel and operation as a "pilot can do a task really well in the simulator but then get in the aircraft and not perform as well." This highlights significant gaps between simulation and real-world performance, with detrimental effects on the pilot performance. As automation comes to the forefront, such gaps could lead to trust failures which compromise safety and pilot effectiveness.

Based on this feedback, a line of questioning was introduced to explore pilot's perceptions on whether a more abstract and "gamified" simulation environment – one designed to introduce and test new concepts removed from other aspects of real-world fidelity representative of a traditional scenario-based simulation approach. Pilots emphasized that "more is better" with benefit to having both training approaches if possible. However, consensus was that pilots could indeed learn or acquire novel skill sets such as UAS deployment in a more abstract simulation environment. These pilots felt this was a valid and useful approach consistent with the "crawl-walk-run" approach to developing concepts of operation (CONOPS) and proficiency around such new technologies. Several interviewees also praised the ability to network simulators together so that larger scale mission scenarios could be run with many pilots in tandem.

Finding 6 - Challenges to training on new systems or updates to existing systems when deployed
All interviewees felt that the current process for receiving training on aircraft technology updates is suboptimal, with one interviewee stating that the current process is "terrible." Best case scenario today, aviators receive a briefing on an aircraft system update from a field representative or another pilot who is an expert (or at the very least has some experience) on the new system. However, the more typical scenario is aviators receive a slide deck or similar update document that they can review on their own. Further, the technology update material can be a challenge for aviators to keep up with since the content is often extensive (i.e., thousands of pages long) and classified, meaning where and how it is consumed can be challenging.

In a worst case scenario, pilots must "adventure learn" new system behaviors. In adventure learning, pilots learn while doing meaning while actually flying the aircraft. In this scenario, the first time the pilot learns about a system update is when they experience it during actual flight. Further complicating this issue is the lack of consistency in fleet aircraft configurations, resulting in some aircraft having updated software and some remain on older configurations. As a result, this increases pilot cognitive burden as such transitions require conscious adaptation. If such gaps persist with increasing automation, even larger expectation/delivery gaps could arise which compromise pilot safety and mission success.

Finding 7 - Desire to maintain crawl-walk-run training methodology
Done correctly today, there is a crawl-walk-run approach to training that was favored by interviewees. Using this methodology, technology updates or learning about new technologies could be incorporated into a next generation type of instruction, leveraging as an example, a Learning Management System (LMS). A holistic LMS approach could be used as a single point of reference to disseminate training content for technology updates, as well as new

technologies. Additionally, an LMS would allow content to be delivered in a more learning-focused manner and hands-on experience than a simple slide deck or document by including exercises, quizzes, and videos along with traditional documentation.

DISCUSSION

From our interview findings, there is an apparent divide between developing capabilities for autonomous systems, and the training given to those pilots to effectively utilize said capabilities. From these recent interviews, when it comes to learning about new technologies, flight simulators can be technologically behind what is actually deployed in the cockpit. That is, there is a lack operational-training system concurrency between future or emerging technologies and the needed training for them. This gap highlights the need to iteratively and jointly improve the understanding and use of human and system/AI capabilities for programs like FVL ahead of launch. Additionally, there is a need for an adaptable and on-demand training platform in support of future technology adoption. Specifically, several pilots noted that with increasing tactical capability in the deployed UAS systems, it would be very important to develop a tactical experience when using such capabilities in simulation. Given that algorithmic capabilities of off-aircraft autonomous UAS may evolve more quickly than on-aircraft updates happening now, high-frequency pilot access to training on such new capabilities becomes paramount to mission success.

Additional key takeaways from the interviews include that aviators need to understand the limitations of a system in addition to how the system should operate. A common theme was the "crawl-walk-run" method of learning where training on a system was layered and given at a pace that allows a pilot to operate the system in isolation before moving onto more complex scenarios. This emphasizes that a crawl-walk-run approach would be essential to the success of programs such as FVL in general and UAS deployments in particular, where advanced teaming is concerned. Since some interviewees discussed their distrust in autonomous systems, there should be importance placed on the level of transparency that autonomous systems have when aiding operators of those systems, in an effort to improve mission-critical decisions.

Note that off-aircraft UAS automation and autonomous capabilities have a different impact on pilot risk and safety than own-aircraft automation. An area of future exploration is to see how quickly pilots can and will adapt to new UAS capabilities given that mission success may be significantly improved by such systems, with little risk to the pilot's own aircraft.

Another takeaway is that the system must behave as intended in demanding situations, otherwise the pilots may ignore the system or even disable it – whether off-aircraft or on. A balance must also be found between providing the pilot with automated assistance and overloading the pilot with too much information. Additionally, the modern technology environment has made aviators accustomed to seeing systems improve over time, therefore having a feedback mechanism between pilots and future system improvements is an important part of training success in the long term.

Interview findings also show that flight simulators are an effective training tool, although there is a breakdown in the effectiveness of flight simulators when they do not match aircraft capabilities. Maintaining simulator parity with aircraft systems will need to be a priority, especially to keep up with the rate at which technologies are being developed.

Next Steps

Interview findings point to a need for a just-in-time learning management system to help aviators better understand, use, and trust future technologies. An initial training capability to meet the 'crawl' stage that incorporates identified future capabilities such as automation, AI, multi-domain sensor fusion, and advanced teaming potentially regardless of context should be developed as a starting point. An LMS and flight simulator could then be incorporated with future capabilities to provide the 'walk' stage. Such a solution provides a modular, integrated, pilot education and in-simulation training environment that provides a comprehensive method and system to teach pilots how to leverage state-of-the-present and emerging technologies. The flight simulator would help support educating the pilot to handle the anticipated massive amounts of data in future systems for enhanced mission success, by situating training in a realistic context. Once sufficiently trained in the simulator, a pilot is then ready to bridge the gap

between simulation and real-life training (i.e., the 'run' stage') and ultimately deployments. One critical factor of the solution proposed based on interview inputs is the incorporation of an LMS that offers an ability to rapidly deploy content as well as the capability to deliver adaptable content modules. This adaptive training approach affords pilots an opportunity to review and test on new technology solutions, before moving on to more advanced flight simulation scenarios. Taking a broader approach to learning technologies in general (even vendor agnostic) can help in providing aviators proper training in a timely manner.

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