# Human Factors Issues in UAS Training

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There is currently a surge in the utilization of Uninhabited Aerial Systems (UAS). Although the importance of the human in the system is often ignored with a focus upon the physical airframe, there are nevertheless numerous human factors issues that must be considered one of which is the training of operators. This paper will describe the inventory and assessment of existing U.S. military and civilian UAS operator training activities and programs conducted by the Arizona State University group of the UAV Alliance, Research, and Curriculum Development Partnership Program. The paper will then discuss various avenues of future research pertinent to operator training including what training backgrounds UAS operators should possess, issues in team training, and use of simulators.

## Introduction

Over the past decade, there has been a major surge in the utilization of Uninhabited Aerial Systems (UAS). The military in particular has employed UASs in mission that are deemed too "dull, dirty, or dangerous" for manned aircraft. Systems such as the U.S. Air Force Predator and U.S. Army Shadow are successfully deployed and have aided the U.S. Armed Forces in reconnaissance, surveillance, and even weapons deployment in theaters such as Afghanistan, Iraq, and Kosovo. This growth in UASs is expected to continue as civil, commercial, and private sectors begin to adopt UASs for missions including, but not limited to, search and rescue, border patrol, homeland security, agricultural crop management, and communications relay. For example, UASs are being flown in increasing numbers to patrol U.S. borders. Such uses will benefit all by helping keep citizens safer, automating tedious jobs, and adding to the convenience of everyday life.

UASs represent a revolution in flight systems such that piloting tasks differ significantly from those of manned aviation. However, the importance of the human (which is still present in the system) is often ignored in favor of focusing on the progression of technology and physical elements such as the airframe. Numerous human factors issues pertaining to the human operator range from restricted fields of vision (the so-called "soda straw view") to remote control and coordination within a larger reconnaissance system. Although good interface design is the first consideration in deployment of effective and safe systems, training follows as a very close second.

This paper focuses on the human factors issues pertinent to training UAS operators. Existing training programs are in the context of military UASs. There is much diversity between the services in regard to UAS training programs with little guidance for selecting one training strategy over another—in effect, to find a common training program that is most effective. Part of this diversity stems from platform differences, but other variance is simply due to history or organizational culture. There is a demand for training research that can provide some guidance for training standards. Training is increasingly important as the supply of trained operators cannot keep pace with the demand and as the importance of good training is highlighted by a relatively high, even unacceptable accident rate.

## U.S. Army Training Program

Unmanned aerial systems have been present in the U.S. Army since the 1930's when drones were used for target practice. Currently, the Army of the 21$^{st}$ century operates three UASs which include the RQ-5 Hunter, the RQ-7 Shadow, and the RQ-11 Raven. As opposed to operators of at least the larger UASs in the Air Force, who are trained as jet pilots first, the primary operators of all Army UASs are enlisted personnel who enter advanced training as UAS pilot candidates straight out of basic training, with no previous flight experience required. It might be noted that, similarly, enlisted personnel enter flight school as Warrant Officer Candidates, along with commissioned officers to become Army Aviators, whereas, all pilot and navigator trainees in the Air Force are commissioned officers.

Once soldiers complete basic training, they arrive at the United States Army Intelligence Center and Fort Huachuca for advanced individual training (AIT) after which they are awarded a Military Occupation Specialty (MOS) for UAS operators (15W) and maintenance (15J or 33W and 52D). Maintenance MOSs receive additional UAS training and an Additional Skill Identifier (ASI) of U2 for the RQ-7 Shadow and U3 for the RQ-5/MQ-5 Hunter (Department of the Army, 2006). For UAS operators, training for the Shadow and the Hunter is conducted at the Aviation Brigade at Ft. Huachuca, and consists of classroom training, simulator training, and flight-line training.

Currency requirements are specific to the UAS being flown. Minimum requirements include a repetition of all base tasks during the daytime and one recurrence of mandatory night tasks as indicated for the given aircraft. Also, one iteration of the mandatory base tasks during Nuclear, Biological and Chemical (NBC) training, any repetition requirements for mission tasks as determined by the unit commander, as well as recurrence requirements for additional tasks as determined by the commander are done (Department of the Army, 1997).

### U.S. Air Force Training Program

UASs in the U.S. Air Force (USAF) have also been used since the 1930s (then the U.S. Army Air Force) with the advent of target drones (Goebel, 2006). The first operational photo-reconnaissance unmanned aircraft, the AQM-34 Ryan Aeronautical Fire Bee, code named "Lightning Bug," was used in the Vietnam War. In the 1990s, the USAF developed the Predator UAS, which is operationally controlled by the USAF's 11th Reconnaissance Squadron at Creech Air Force Base in Nevada. The USAF also developed the Global Hawk UAS in the late 1990s as well as initiated the High-Altitude, Long Endurance (HAE) UAS program, of which the USAF is the executive agency.

Currently, the MQ-1 Predator and RQ-4 Global Hawk are operated primarily by rated pilots serving a three-year "career-broadening" tour, while a few are navigators. In most cases, both pilots and navigators hold FAA commercial certificates with instrument ratings. However, the USAF vision is to develop a new career field to staff these billets. Part of this transformation will be the creation of a Remotely Piloted Aircraft (RPA) training program for new USAF officers and enlisted personnel to transition directly into RPA and UAS major weapon systems.

Due to the costs involved and shortage of aviators for manned aircraft, there are currently several proposed alternatives for future UAS training. Because UASs such at the USAF Global Hawk do not require traditional stick-and-rudder skills to operate, experts contend that an engineer with some pilot background (knowledge of basic flight dynamics, weather, instrument flight rules, FAA rules, etc.), experience with home-computer flight-simulator games, extensive familiarity with flight systems and mission planning, and 250 to 500 hours of simulator time would be a model candidate as a remote pilot for the Global Hawk (Hoffman, 2005).

Alternatively, a new plan under the Predator UAS Initial Qualification Training (IQT), calls for an all-volunteer operator force which would (1) use contracted civil aviation or USAF Initial Flight Training (IFT) to obtain private pilot's proficiency, (2) use contracted civil aviation training to obtain the equivalent of a commercial instrument qualification, and (3) require attendance and completion of Predator IQT. The non-rated officer, now a trained, fully qualified "UAS pilot" ready for mission qualification training, would serve a three-year tour (or longer). A private, USAF–sponsored IFT program also exists, which includes a full check ride and solo flight for pilot trainees in a Cessna 172. For an extra 80 hours of training, and at additional cost (approximately $4,800 in 2005 US dollars) per individual, each trainee would receive a private pilot's license with an instrument rating (Hoffman, 2005).

### Civilian Training of UAS Operators

Civilian training of UAS operators has recently received considerable attention. The primary question in civilian training is whether actual flight experience is or should be required. McCarley and Wickens (2005) describe how past research has come to conflicting conclusions as to whether UAS operators will benefit from experience piloting a manned aircraft. Schreiber, Lyon, Martin, and Confer (2002) examined the effects of prior flight experience on novice operators' skill acquisition and transfer to a Predator UAS simulation. In general, flight experience reduced the number of training trials required for operators to reach a criterion level of performance on a set of basic maneuvering and landing tasks, and improved operator performance on a subsequent reconnaissance task. McCarley and Wickens however note that other findings have suggested that UAS operators need not be rated aviators.

As of this writing, there are no FAA pilot certification processes or procedures for UAS pilots promulgated for operating an unmanned aerial vehicle in the National Airspace System. Many opinions abound with regard to pilot training standards. The FAA is currently surveying and integrating findings from existing literature on the human factors of UAS operation to identify specific research questions that remain to be addressed in preparation for the impending integration of UASs into the National Airspace System (NAS); to include the training and selection of civilian UAS operators (McCarley & Wickens, 2004). Pilot training applicable to civilian UAS training would likely include instruction in subjects such as the Air Traffic Control system, communication, instrument flight, navigation, and flight operations.

**Training Issues Identified**

Five training issues were found by identifying groups and individuals thought to be knowledgeable in UAS training and contacting them directly for references and research papers. A review of relevant literature was also conducted. The following issues, summarized below, characterize the state-of-the-art in training and highlight gaps in the literature that require further research. Following each issue is a corresponding research agenda presenting major questions/avenues for further research.

*Training Background* The background of UAS operators has been a much debated topic since the early inception of unmanned vehicles. Operator qualifications, including their training backgrounds (i.e., experience with video gaming and interest in model radio-controlled aircraft) has seen much controversy (Weeks, 2000). The sheer number of different UASs, interfaces, control schemes, and possible missions makes the determination of what experiences and knowledge an operator should possess all the more difficult. Adding to the difficulty is the argument as to whether video gamers or pilots make better operators, and the different operating doctrines that are found between military forces, the FAA, and other countries. In addition the various branches of the military all have differing views as to what background an incoming UAS operator should have.

The recent Third Annual Human Factors of UAVs Workshop in 2006 hosted by the Cognitive Engineering Research Institute (CERI) located in Mesa, Arizona, also highlighted many issues surrounding the backgrounds of operators in relation to training. A break-out session at the Third Annual Human Factors of UAVs Workshop was devoted to the discussion of operator training, the researchers, developers, and operators (from the U.S. Army) attending the session agreed that ideally, operators should be trained for excellence and not to just meet a minimum requirement. To do so, performance metrics for use in the field or in simulators must be developed. Prior to this, however, Knowledge, Skills and Abilities (KSAs) and Mission Essential Competencies (MECs) based on the mission/task and platform must be identified which will also entail the classification of UASs in order to standardize training (due to the variability in interfaces, control schemes, and UASs in existence). The session members also agreed that what backgrounds operators should come with needs to be established. For example, military operators should have a tactical background *but what of civilian operators? Can video gamers serve as suitable operators? Will they need flight training?* Determination of individual abilities and personality differences will also have to be taken into account as well as the trainability of KSAs such as spatial ability.

*Use of Simulation and Training Devices* In addition to the training background issues identified, there is a great need for research in the area of simulation and training devices. The benefits of simulated training are numerous as it leads to lower training costs, safer training methods, and virtually no accidents or damages. As such, it has been recognized throughout the aviation community that simulators are a valuable training and re-currency tool. As suggested by Ryder, Scolaro, and Stokes (2001), training cost considerations encourage the use of simulation-based training over flight training to the extent that training efficacy is not reduced. It is more efficient and often easier to provide UAS training via simulator than real-time flight.

Any research within this area is relevant for both simulation training devices as well as the actual UAS interface since under most circumstances when operators control their vehicle by means of a screen or display, the simulator these operators train with will utilize the same controls and interface as the actual system used to control a real UAS. Data is needed to support this however. Training specifics must be a function of the KSAs and the platform. Furthermore, there may be some skills that are not well-trained through a simulator. Also, because it is a simulator, it is possible to train solely on part of the task, but is this more effective than whole-task training? Simulators also allow the operator to acquire experience on missions that may be otherwise dangerous or costly to perform with a real aircraft. The research question is, therefore, *how should simulation be most effectively used to support UAS operator training?* Again, KSAs and MECs should provide information on skills that need to be trained and controlled experimentation or quasi-experimentation in the field can address simulator effectiveness.

*Mitigating Constraints through Training* UAS operations are riddled with constraints that make the task more challenging. For instance, fatigue is common in UAS operations as operators must work long shifts in concert with the capabilities of machines designed for endurance. What can training do to mitigate the effects of *fatigue* or the related issue of *boredom* and performance losses associated with *vigilance decrements?* There are also environmental constraints that make operations challenging such as *bad weather* that can seriously compromise the safety and performance of the UAS. Additionally, there are organizational constraints such as the *operator to system ratio* which is currently 2:1 or 3:1 depending on the platform. The current trend in the military is the reduction of this ratio to 1:1 and even 1:2, 1:3, and 1:4. The USAF has recently claimed that this is feasible with Global Hawk. However, the Global Hawk flies preprogrammed missions at 60,000 ft, above weather and other traffic. There are human factors questions concerning the safest and most effective ratio for various UASs. But *what are the implications of the ratio for training?*

Automation has been suggested and in some cases implemented as a solution to many of these constraints. Automation can presumably decrease workload, allowing a single person to control a larger number of vehicles. Automation may also help mitigate fatigue, boredom or vigilance by better regulating workload and it may also provide assistance in bad weather. But automation does not always serve a training function. Automation may, however, serve a training function in the form of intelligent agents that provide just-in-time training or assistance in handling these various constraints. If the agent came equipped with pedagogical techniques to explain its actions to the operator or coach the operator through the appropriate actions then it could accomplish both operational and training functions. In this case the research question is *how can technology be used to provide just-in-time or adaptive training during operations in order to mitigate constraints?* There is work that can be adopted on just-in-time training from other domains such as human-computer interaction, but its application in this dynamic, high tempo setting requires significant research so that the training does not interfere with operations.

*Team Training* Studies on team training are scarce, but work is being done in the area. The research efforts at the Cognitive Engineering on Team Tasks (CERTT) Laboratory in Mesa, Arizona, have focused on the team dynamics associated with UAS operation and the acquisition of team-level skills in the context of a UAS Synthetic Task Environment (STE). Specifically the lab, shown in Figure 1, is interested in the study of the cognitive activities such as planning, decision making, and situation assessment that are carried out by teams in the UAS setting. The processes which include team coordination are referred to as team cognition which is assumed to be at the center of team performance in highly cognitive tasks such as UAS control (Cooke, Pedersen, Connor, Gorman, & Andrews, 2006).


***Figure 1.*** CERTT Lab participant and experimenter consoles

The CERTT UAS-STE was abstracted from a cognitive task analysis of the Predator UAS control scheme (Cooke & Shope, 2004), and emphasizes psychological fidelity such that operations such as decision-making, coordination, and planning are examined. The UAS-STE is controlled by a three-person team whose mission it is to take reconnaissance photos at specific target waypoints. The team members involved in the UAS-STE are the Air Vehicle Operator (AVO) who flies the UAS by controlling the heading, altitude, and airspeed; the Payload Operator (PLO) who controls camera settings and takes reconnaissance photos; and the Data Exploitation, Mission Planning and Communications Operator (DEMPC) who plans the mission and acts as the navigator. Individual team members are provided with distinct, though overlapping training; have unique, yet interdependent roles; and are each presented with different and overlapping information during missions. Therefore, to successfully complete a mission, the team members need to share information with one another in a coordinated fashion. Teams are run through missions that contain specific amounts of targets and last 40 minutes each. Measures collected include team performance (based on a composite of team-level outcome variables), team process behaviors, situation awareness behaviors, teamwork knowledge, task work knowledge, and communication data.

UAS operations require teamwork. Even if one or more vehicles are controlled by a single individual (i.e., a 1:1 ratio), that individual still needs to be in communication with others who have information or information requests pertinent to weather, threats, intelligence, ground operations, air operations, and even other aerial vehicles. Further, team members in these scenarios are often geographically distributed providing additional challenges to team performance. Issues of team coordination and crew composition are also important for questions of staffing and decisions on the optimal operator/vehicle ratio

Crew Resource Management has been widely accepted as a team training regime for manned aviation (Salas, Burke, Bowers, & Wilson, 2001) and is gradually being adopted by other industries such as medicine and transportation. The goal of CRM is to improve team coordination and situation awareness. Likewise, team training should be an important part of UAS operator training. The research question is *how should team training be incorporated into UAS operator training for maximum safety and efficiency?* Some data from the CERTT Lab team skills analysis (Cooke, DeJoode, Pedersen, Gorman, Connor, & Kiekel, 2004) indicate that coordination can be learned and can transfer to other tasks. These results support the possibility of facilitating team performance through team training.

*Learning-Acquisition & Retention* Related to the discussion of the acquisition of team skills above, the concept of skills retention has been of great interest to the military in its need and desire to minimize forgetting and maintain combat readiness while keeping training costs as low as possible (Hagman & Rose 1983). Wisher, Sabol, and Ellis (1999) describe three skills/subtasks which are present in all military tasks and are subject to forgetting: (1) retrieval of facts from memory, (2) ability to combine and evaluate incoming information, and (3) execution of the chosen actions or procedural steps. However, with the cognitive complexity and reliance on teams in today's tasks, especially that which is seen in the operation of UASs, the study of skills retention is of import.

Of special interest also is the retention of coordination and communication skills in the context of UAS operations. In a recent study conducted in the CERTT Laboratory, 39 three-person teams participated in 8 missions spread across one 6.5 hour session and a second 3.5 hour session that was scheduled either 3-6 or 10-13 weeks after the first session. In this experiment, team familiarity was also manipulated such that half of the teams were decomposed after the first session and randomly reassembled into new teams for the second session. Second session teams under this condition were unfamiliar with each other but retained their individual roles assigned in the first session. The retention interval occurred after Mission 5.

Team performance results, indicated that there was no decrement for short-same $t(9) = .236$, $p = .819$ or long-same $t(8) = -2.167$, $p = .062$ teams though short-mixed and long-mixed teams experienced a significant decrement $t(9) = -3.318$, $p = .009$ and $t(9) = -3.758$, $p = .005$, respectively after the retention interval. Whereas short-same teams did not show any decrement, they also did not exhibit improvement after the interval unlike the other teams which did. An interesting finding from this experiment is that though mixed teams showed a decrement in their performance after the interval, they did show an improvement in team process (coordination, communication, timeliness of interactions, situation awareness behavior), whereas same teams showed no changes in process after the retention interval (see Figure 2 below).

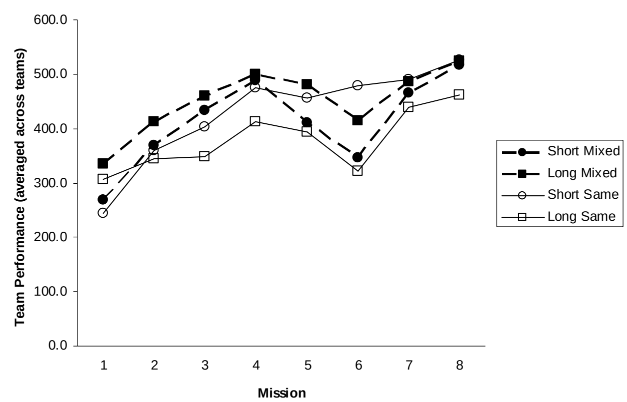


***Figure 2.*** Team performance across all missions

At the most basic level, training effectiveness can be captured in terms of pre-post or before-after difference scores. Individuals or teams should perform at a significantly higher level after training compared to before. However, there is much to be gained from examining the developmental course of skill acquisition and retention. *How quickly do individuals or teams learn? How long is trained material retained with periods in which the skill is not practiced? What is the savings or degree to which learning is accelerated the second time around? What factors influence the acquisition and retention of skill and what types of training facilitate acquisition and retention?* Answers to these questions can help us understand the mechanics of individual or team leaning so that more effective training programs can be designed.

## Conclusions

Since training comes in second place to interface design in the deployment of effective and safe UASs, the ASU team of the UAV Alliance, Research and Curriculum Development Partnership Project identified potential human factors concerns in operator/pilot training and to propose follow-on tasks to demonstrate one or more research initiative relating to the concerns identified. The investigation by the ASU team revealed that there is a need for training research that can provide some guidance for training standards: (1), to keep pace with the increasing demand for trained UAS operators; and (2), to overcome the relatively high historical accident rate in UAS operations. As government, civil, commercial, and private sectors continue to adopt and utilize UASs, The need for advances in operator training will become paramount in ensuring the safe operation in both the military and in the NAS.

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