A Navy X-47B Unmanned Combat Air System demonstrator aircraft prepares to execute a touch and go landing on the flight deck of the aircraft carrier USS George H.W. Bush (CVN 77) as the ship conducts flight operations in the Atlantic Ocean on May 17, 2013. This marks the first time any unmanned aircraft has completed a touch and go maneuver at sea. Unmanned aerial vehicles such as the X-47B currently fly in restricted airspace. Efforts are underway to integrate manned and unmanned traffic into the same airspace, but significant human factors challenges must first be addressed.

FLIGHT IN NON-SEGREGATED AIRSPACE

Paving the way for fully integrated manned and unmanned airspace means addressing myriad challenges both technical and psychological- and that's just the beginning!

LT Eric S. Vorm

Present day headlines in military aviation safety are dominated by persistent physiological episodes in a variety of jet platforms. Teams of scientists and engineers are working around the clock as we speak, trying desperately to understand and model the problem in order to identify a solution. Like spatial disorientation in the late 1990s and early 2000s, or runway incursions and other carrier-based aviation challenges of the early-to-mid 20th century, this current challenge has the aviation (and the Aerospace Experimental Psychology) communities pulling out all the stops.

From the standpoint of aviation safety, it is an unfortunate reality that many of the issues we wrestle with only become apparent once an aircraft is fielded. A cost-based analysis would suggest that it is far easier (and cheaper) to address issues of safety while the aircraft or system is under development, when its components are somewhat malleable and receptive to adjustment. Despite significant investment in time and testing, however, many issues related to safety often go unnoticed or slip through the cracks during the run up to production.

As AEPs, we are often fortunate to serve at the bleeding edge of the acquisition of aviation systems. Remaining cognizant of the state of the science while keeping an eye on the horizon of development is therefore not merely a good idea, but a critical one as well.

This article introduces a relative newcomer to the aviation safety problem space: human-automation interaction. In it, I seek to inform readers of a potential near-term challenge in the development of a sense and avoid capability for unmanned systems to enable unmanned flight into non-segregated airspace. I outline the current and potential future challenges of the proposed systems design, and address possible areas where AEPs can provide meaningful impact.

As of the date of this publication, unmanned aerial systems (UAS) do not have dedicated airspace in which to operate, both in the US and internationally. Current FAA policy for UAS operations is that "no person may operate a UAS, including tethered UAS, outside of active restricted, prohibited or warning areas in the [national airspace] NAS without specific authority, with the exception of a model aircraft flown for hobby or recreational purposes or an Optionally Piloted Aircraft that has a pilot on board" [1].

There has been a great deal of effort extended towards integration of UAS into the full range of airspace for over a decade [2]. This is because a variety of UAS use cases and capabilities (such as cargo UAS, for example) are currently impeded by the inability to fly in non-segregated airspace. Amongst the variety of challenges that currently limit UAS operations to special, restricted airspace, the most applicable to the field of aviation human factors is the common requirement of self-separation.

Self-separation is a fundamental concept of aviation safety, originating from the earliest days of aviation before the advent of radar and modern air-traffic control. It remains a fundamental requirement of all aircraft, regardless of size or type. Current federal aviation regulations define this requirement as "when weather conditions permit, regardless of whether an operation is conducted under instrument flight rules or visual flight rules, vigilance shall be maintained by each person operating an aircraft so as to see and avoid other aircraft. When a rule of this section gives another aircraft the right-of-way, the pilot shall give way to that aircraft and may not pass over, under, or ahead of it unless well clear [3]." This defines the concept of 'see and avoid,' and is commonly known as the 'remain well clear' rule in aviation, which serves as the foundation of all right-of-way rules and regulations.

Because the pilot in command of a UAS is geographically removed from the vehicle, both the restricted viewing aperture and the pronounced latency involved in scanning via remote cameras means that they cannot accept visual separation or visual approach clearances [1]. Functionally this means that the responsibility for separation for all UAS (larger than 55 pounds) is assigned to the air traffic controller (ATC). This is a considerable problem because there are wide ranges of airspace that are not covered by ATC. The development of a system that could provide means of UAS self-separation without the use of ATC, therefore, has been a principal focus in the effort towards complete integration of UAS in the national and international airspace since the full-scale introduction of type 2 and above UAS [2].

LT Eric Vorm, AEP #149, pilots an MQ-9 Reaper UAV during a training event at Holloman AirForce base, New Mexico. UAVs such as the MQ-9 will hopefully soon be fully integrated into the national airspace.

Efforts to provide UAS 'sense and avoid' (SAA) capabilities (an adaptation of the 'see and avoid' concept from general aviation) have resulted in a variety of technological approaches. While these approaches differ in the methods with which the UAS detects and interprets potential intrusion threats, all prototype systems reviewed by this author have one fundamental factor in common: the extensive use of automation.

Virtually all group 2 or higher UAS make use of extensive libraries of automated routines and subroutines. These serve as functional macros to execute functions autonomously, and mostly work according to pre-scripted, algorithmic heuristics.

Many of these functions are not entirely dissimilar from the capabilities of many large commercial aircraft that utilize a flight management system (i.e., autopilot). In both cases, given appropriate operating conditions, a computer can provide heading and altitude inputs to the control surfaces, and can perform a variety of maneuvers, including takeoffs and approaches. These forms of automation, while not without their own challenges [4], are less worrisome, in part because many have been in operation for decades already with excellent track records.

The sort of automation proposed in future SAA systems, however, represents a significant leap in terms of the scope and authority these systems have to infer, decide, and act with little, or in some cases no human input. In order to understand both the human factors challenges presented by these types of automated systems, as well as the opportunities that AEPs may have in addressing them, it is first necessary to define the problem space a bit more.

For the purposes of considering the human performance implications of automation, we can use a simple binary taxonomy to differ between the kinds of automation that (a) assists users in obtaining and maintaining awareness of their environment, and (b) that assists users in making decisions.

Automation that assists users by improving their awareness (herein referred to as 'situation assessment automation') does so primarily by integrating multiple data streams into consolidated displays, and providing alerts when systems are out of safe operating ranges. These systems primarily help users by allowing them to offload what would otherwise be additional monitoring tasks onto the computer, thereby freeing them to engage in more mentally demanding tasks (like flying the airplane). In the event that a decision must be made, the system generates some form of alert, making them aware of the situation. Common aviation examples of these systems include fuel level, airspeed, or stall warnings.

Automation that assists users by providing recommendations (herein referred to as 'decision support automation') does so primarily by fusing data from other systems with a heuristic evaluation of options, and then presenting those options to the user, often in a prioritized fashion, or in some cases eliminating all but one option. In the event that a decision must be made, because of the assistance of the computer, the user is able to arrive at a conclusion and act on that conclusion much more efficiently. Common aviation examples of these systems include traffic collision avoidance systems (TCAS), and the modern flight management systems (FMS) in most commercial flight decks, both of which issue alerts combined with some form of recommendation guidance (i.e., "pull up!" "pull up!").

At first glance, decision support automation has great appeal, and in many cases airline pilots have expressed a preference for these types of systems, mostly because of the cognitive efficiency they provide [5]. A granular comparison between the effects of decision aiding automation with situation assessment automation, however, reveals that the former can be problematic because of the way it can subtly influence human decision making.

Research has demonstrated that humans are more aware of a developing situation and their operating environment when they actually do an action as opposed to when they passively observe another agent perform the action (whether another human, or an automated agent) [6]. Researchers investigating this phenomena have observed that the mere act of generating an action (i.e., doing or deciding something yourself) rather than passively watching it being generated solidifies that action more robustly in memory— a phenomenon known as the 'generation effect' [7]. This 'see-do' dichotomy underlies the qualitative differences that systems providing automated alerts versus systems providing automated suggestions can have on human decision making.

In situation assessment automation, the user is provided an alert which directs their attention to a developing situation. They must then evaluate the situation, decide on a variety of options, and act. This represents the full cycle of human decision making, from input to output, which according to the theory behind the generation effect suggests that this results in a more solid understanding of that decision and its consequences in memory, i.e., greater situation awareness. In contrast, decision support automation provides an assessment of the situation AND recommends an action, which the operator then decides whether or not to accept or reject. In this case the operator does not benefit from the full sequence of decision making and so has a poorer understanding and mental representation of the system state and the consequences of actions, i.e., poorer situation awareness.

In emergencies, such as the ground collision avoidance example from earlier ("pull up") there is little concern that decision support automation can have a detrimental effect on decision making. But in situations that allow for anything more than an instinctive, reflexive judgement, there is ample evidence to justify concern, both from empirical research, as well as from mishap reports.

Several studies have demonstrated that users tend to perform better when utilizing decision aiding automation, but only when that automation is accurate and correct [8], [9]. When those recommendations are made incorrectly, either because of inaccurate system inputs or because the data on which the system derives its recommendations is fuzzy or probabilistic, then user performance suffers [10], [11]. As a real-world example, consider Air France flight 447. While transiting from Rio de Janeiro to Paris, the flight briefly encountered inclement weather which caused the pitot tubes to fill with ice for a short time. This in turn caused the speed indicators to read slower than actual speed, which caused the autopilot to register a stall warning, after which the autopilot disengaged (as it was designed to do). The pilots, unaware of the pitot tubes causing incorrect speed, misinterpreted the situation and, rather than responding to the stall warning appropriately, provided incorrect inputs which further destabilized the flight, causing a prolonged stall which ultimately led to the flight impacting the ocean. In this example, the computer incorrectly assessed the situation due to faulty data (incorrect speed caused by pitot tube impaction). Had the pilots been able to correctly assess the situation, they likely would have been able to notice that they were in fact not in a stall, and could have therefore made an appropriate decision not to interfere (it is worth noting here that the mishap report actually concluded that if the pilots were to have left the controls alone, the flight would have continued on without issue). Due to the added confusion caused by the automated alert and corrective guidance provided by the FMS, combined with the stress of flying in inclement weather, the pilots became confused and panicked, and their subsequent decisions ultimately lost the lives of all on board [12].

So what can be done?

Distinct from other human factors involving controlling UAS [13], the principal factor involved in developing an SAA system for UAS is addressing how to employ higher, more aggressive forms of automation in manners that do not lead to conflicts in human performance and judgement. Unfortunately, the kind of automation proposed in future SAA systems largely removes the evaluative component from the user, and therefore is more prone to lower situation awareness and understanding of a developing situation [14].

LT Mike Natali, AEP #150, pilots an MQ-9 Reaper UAV during a training event at Holloman AirForce base, New Mexico. Training events such as these provide tremendous insights into the rigors and challenges that aircrews face on a daily basis. The role of UAVs in military aviation has expanded tremendously since being formally introduced in the modern era. AEPs and other researchers are hard at work developing techniques, strategies, and doctrine to help facilitate the full integration of UAVs into the national airspace.

Although up until recently decision support automation was largely only present in commercial aviation or nuclear process control, the promulgation of UAS, both in military as well as civilian dedicated airspace, presents human factors engineers (and by proxy AEPs) with unique opportunities to influence the future design of these systems in at least three following ways, starting from the bottom up:

1. Those involved in basic and applied research can continue to explore the rich domain of human-automation interaction, and in doing so can further identify risk factors, mitigation techniques, and design guidelines to help address these challenges.

2. Those involved in systems engineering, development and acquisition can provide inputs to the team, sharing lessons learned and helping to guide the acquisition and employment of decision support automation in future systems.

3. Those involved in doctrine can advocate for greater awareness of these human-automation conflicts (and for human factors as a whole). They can also serve to inform decisions related to a variety of policies including the training curriculum, as well as the higher level policies involved in how new systems are tested, evaluated, and fielded.

Conclusion

A number of indicators such as the UAS Roadmap [15] and the DoD's third offset strategy [16], among others, suggest that automation will be a near-ubiquitous element in most future systems.

From the standpoint of safety, it is in our collective best interest to get in front of these challenges and address them while they are still on the drawing board, rather than waiting until they are on the front pages of tomorrow's news.

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