Journal of Aviation/Aerospace Education & Research

Volume 17
Number 3 *JAAER Spring 2008*

Article 3

Spring 2008

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FORUM

THE FLIGHT CREW AND AUTOMATION

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"Automation is the allocation of functions to machines that would otherwise be allocated to humans" (Funk et al, 1999). Automation on the flight deck has continued to grow throughout the years, with each new generation of air transport aircraft containing more automation than the last. As flight deck automation progresses at an increasingly rapid rate, the interaction between the pilot and automation will become increasingly more complex. These advances in automation have helped to greatly improve the utility of aircraft, allowing them to do things once thought impossible, such as landing in zero-zero conditions, near full-automated take-offs, and optimizing fuel efficiency. Flight deck automation has brought improvements to the flight deck, but it has also increased the potential for errors in the essential interactions between the automated systems and the human flight crew. The main concern regarding automation on the flight deck is the flight crew losing situational awareness. Other concerns include: loss of manual skill, overconfidence in automation, and difficulty in predicting and monitoring what the automation is doing or will do. There exists a real need to eliminate or mitigate these problems, which pose a significant threat to safety.

Automation has helped to make air travel safer and improvements have been seen, however as Major Wesley A. Olson (2001, p. 7) notes, "while the overall rate of aviation accidents has declined dramatically over the last 30 years, little improvement has been seen over the last 15 years despite the continued evolution and improvement of automated cockpit systems." Automation alone can go only so far, improving upon the interactions between automation and the human flight crew is a must for continued improvements upon safety and utility.

The main concern with regards to automation on the flight deck is the loss of situational awareness on the side of the human flight crew. Such a loss of situational awareness poses a real threat to safety, and there are a multitude of accident reports that demonstrate the threat. A number of studies have noted that the human flight crew is at a greater risk to lose situational awareness as the amount of automation increases. It has been cited by Mica R. Endsley (1996, p. 4) that "the increased display complexity and computerized display format reduces the perceptual salience of information, even if it is available." The claim is further supported by Olson (2001, p. 13) who stated that "in the absence of salient indications (i.e., flashing lights, color changes, etc.), pilots often do not pay attention to potentially relevant information." Thus, the way the information is presented to the crew and the salience of that information is a contributing factor to a loss of situational awareness on the part of the flight crew. Making the information available does not suffice; the information must utilize salient indications to draw the attention of the flight crew. Without doing so the crew is likely to overlook or miss important or critical information. Further, automation has caused the flight crew to go from an active role on the flight deck to a passive role. As such, it has removed the flight crew from the loop, and made them more passive decision makers than they were prior to these advanced automated systems. Endsley (1996, p. 3) found that in a study dealing with automated automobiles, "subjects' situation awareness was lower under fully automated and semi-automated conditions than under manual performance in an automobile navigation task." A similar problem arises with automation on the flight deck. The study showed how automation can negatively impact a human operator's situational awareness.

A contributing factor for the loss of situational awareness due to automation is in the feedback given to the flight crew, which they would receive normally in aircraft with little to no automation. The effects of this lack of feedback traditionally found in aircraft can be seen through

> "the development of electronic fly-by wire flight controls in the F-16 [which] led to problems in determining airspeed and maintain[ing] proper flight control, as the vibration information that usually came through the flight stick was suddenly missing (even though the needed information was clearly indicated on traditional visual displays)." (qtd. in Endsley, 1996, p. 4)

Even though the information was present, the lack of the normal non-flyby wire tactile information led to a loss of situational awareness among the pilots of the F-16. The problem has been corrected with the addition of artificial vibrations on the flight stick, which provide the pilot with the tactile sensations they would normally feel.

Loss of situational awareness has also been contributed to information overload and is cited by Olson (2001, p. 13) as having to do with "automated systems...present[ing] more information than the pilot can process in the time available." This means that even if the information is available to the flight crew they may not be able to pick it out among the overload of information they are receiving in a limited space of time. The human flight crew must be able to sort through the various information to pick out what is relevant and what is not. With an overload of information, the flight crew is unable to sort through the information in a timely and efficient manner, leading to uninformed or semi-informed decision making. Allowing the flight crew easy access to the raw data, which they are used to seeing on non-automated aircraft, may help to alleviate this problem of information overload.

Proper crew-machine interaction is essential to maintaining situational awareness and a safe and efficient flight. There are, however, components in the automation that block effective interaction. Johan Rignér and Sidney Dekker (2000, p. 2) state that this interaction may be blocked "because pilots can direct the automation privately...the automation is silent about what it does to the aircraft, and because interactions with the computers often occur when there is also a lot of other work to do." Rignér and Dekker (2000, p. 2) go on to address the need for a change in training because the training "leaves few opportunities for aircrews to learn about the broader and [sic] more subtle influences of automation...and on the need to coordinate despite of flight deck designs...that routinely conspire against the ability to coordinate." If training were to effectively allow flight crews to analyze the influences of automation and the changes in the role of the flight crew, they may be better prepared to deal with some of the problems associated with automation and maintain a greater situational awareness throughout the flight.

Along with improving flight crew training another concern that has been raised with the increased use of automation is the potential for a loss of manual skill. A study concerning the manual skill between airline pilots who flew primarily "steam" gauges and those who flew the automated glass cockpit was conducted to see if automation caused pilots to lose manual skill. A number of observations were made: "when given close crossing restrictions, the steam gauge crews were more adept at the mental math and usually maneuvered the aircraft in a smoother manner to make the restriction. On the other hand, the glass cockpit crews tended to go 'heads down' and tried to solve the crossing restriction on the FMS" (Veillette, 2006). When the flight crew goes heads down, they are unable to fly the aircraft as effectively, proven further by the fact that "many of the glass cockpit crews mismanaged their time trying to figure out how to insert the crossing restriction in the box, becoming so absorbed in the process that they'd barely make the assignment" (Veillette, 2006). The glass cockpit flight crews have a tendency to go heads down when they get a change to their clearance instead of flying the aircraft. Not only does this affect their ability to fly the aircraft if the automation fails, it also negatively impacts their situational awareness. By directing attention away from the flight and to the Flight Management System, they are diverting attention from important information about the flight and from their objective, whether that is a crossing restriction or a different instruction given by air traffic control. Not only may this lead to not meeting the clearance, it can also compromise safety.

Evidence exists to suggest that as the flight crew becomes increasingly accustomed to the everyday, repetitive use of automation, they begin to put increasing confidence into that automation. The overuse of automation, in turn, may lead to the flight crew becoming overconfident in the automation system that their aircraft is equipped with. According to Ken Funk et al (2007), "pilots may become complacent because they are overconfident in and uncritical of automation, and fail to exercise appropriate vigilance, sometimes to the extent of abdicating responsibility to it. This can lead to unsafe conditions." The claim has been supported by a number of accident and incident investigations, such as the investigation by the Investigation Commission of Ministry of Transport in their 1989 report, where it was cited on page 60 that "the A320 has new features which may have inspired some overconfidence in the mind of the Captain." Here is a prime example how overconfidence in the capabilities of advanced automated systems can lead the flight crew into let their guard down and lose their situational awareness leading to a compromise in safety.

In regards to automation and the subsequent loss of situational awareness in the cockpit, a further concern is in the flight crew having difficulty predicting what the automation will do. The reason for difficulty in predicting what automation will do is due in part to what form of feedback the automated system gives to the flight crew. As stated by Olson (2001, p. 18), "automated systems often lack the ability to clarify ambiguous or misunderstood instructions," which can lead to the aircraft and automated systems not performing the functions the flight crew had intended the automation to perform, leading the flight crew to be surprised by the resulting actions taken by the automated systems. There are a number of reasons why the flight crew may be surprised by, or unable to predict, the actions of the automated systems. Inability to predict the actions, or being surprised by the actions, of the automated system may be explained by Guy A. Boy and P. Carlo Cacciabue (1997, p. 4), who stated, "automation was implemented from an engineering perspective rather than from a human operator perspective." Since automation was not implemented from a human operator perspective, it could provide at least a partial explanation as to why the flight crew is surprised by actions taken by the automation and at times unable to predict what it will do. Boy goes on to make an astute observation that "automation should be driven by actual needs rather than by technological options" (Boy & Cacciabue, 1997, p. 7). If automation was driven by needs, it might help to mitigate the loss of situational awareness, and help the flight crew to better predict what actions the automation will take. Either way, including flight crews in the design of automated systems may help to reduce these problems.

In conclusion, the need to mitigate or eliminate the loss of situational awareness that occurs as automation advances is real. It has been documented that with the ever-advancing levels of automation, flight crews can and do lose situational awareness, and without hand-flying, pilots will lose effectiveness when dealing with situations where the automation has failed. Possible ways to help mitigate or eliminate this loss of situational awareness include: introducing automation earlier in training, allowing flight crews input on the design, functions, and displays of the automated system, as well as designing automation from a human perspective as opposed to an engineering one. Further, allowing the flight crew easy access to the raw data, which is normally present, may help alleviate the problems in interaction which face the human flight crew. Utilizing automation to augment the human flight crew and provide them with the information and performance they need or request in a timely, efficient, and presentable manner may increase their situational awareness by giving them the best of both worlds. Also, having flight crews routinely and systematically hand-fly the aircraft will aid in keeping the crew keen in both the use of automation and in managing the flight should that automation fail. There are a multitude of ways to improve on automated systems; these are but a few potential solutions which can help to improve these essential systems. Automation is here now, and will remain here. It has allowed us to gain more utilization of aircraft in a more efficient manner. As such, improving on the human-machine interaction and keeping the flight crew aware of the situation and in the loop at all times, and making the automated systems an effective crew partner, is a must.✈

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