

## General Aviation Training for “Automation Surprise”

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What is it doing? Why is it doing that? Why didn't it do what I wanted? These questions when voiced by a pilot during flight are all indicators of the phenomenon known generally as “automation surprise.”<sup>1</sup> The phenomenon has been a factor in the operation of sophisticated, highly automated transport category aircraft for some time now, but with the use of more technologically advanced aircraft, automation surprise is now becoming common in general aviation. Pilots' reactions, after having experienced an automation surprise, will range from curiosity and concern to outright hostility with the system, but most will assume that the frequency of these events should be reduced by practice and more experience. However, one of the more interesting things about automation surprise is that it is not limited to inexperienced users of these new cockpit systems. Even after considerable training, experienced pilots can still be subjected to this phenomenon. An industry wide training effort has been in place for some time among the major air carriers to reduce the frequency of these occurrences and to minimize the severity of the resultant risks. Training for automation surprise is much less organized among the general aviation community, but the need is very real. The effectiveness of this training will depend on a better understanding of the nature of automated systems and the limitations that are implicit in the design of human-machine interfaces. It is this author's opinion that phenomenon of “automation surprise” can not be totally eliminated from the current (and possibly future) operations of technologically advanced aircraft. This is because the digital logic implicit in the programming of highly sophisticated flight and navigation systems can not be adequately replicated by human operators.

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<sup>1</sup> Woods, et. al. 1994

Automation surprise typically occurs in one of two ways in the cockpits of technologically advanced aircraft. The first is the event that is unexpected or uncommanded, and represents a system change that is either recognized or not recognized by the pilot. An example would be an unexpected change in navigation mode by the flight director from “NAV” mode to “PIT” or “DR” mode. The second type of automation surprise common in general aviation is an unexpected result from a commanded change, such as in the case of an autopilot failing to capture an altitude when the pilot has input (and expects) a preselected level. In both cases, the pilot, once he has discovered the discrepancy, becomes momentarily confused and, often, has no immediate idea of what action should be taken to correct the situation, at least with respect to the automated system. This confusion and uncertainty is not the result of a lack of understanding or awareness of the state of the aircraft, but the lack of awareness as to the state of the automation.

Pilots, flight instructors and aviation educators are quite familiar with the concept known as “loss of situational awareness.” Normally, a loss of situational awareness refers to a pilot’s lack of understanding of the physical surroundings of the aircraft and/or the current state of the aircraft. However, the types of unexpected events that constitute an automation surprise can also be considered examples of the loss of situational awareness. The automation system in a modern aircraft is a complex system that exists within its own digital environment. This digital environment has a structural architecture that includes a variety (often a very large variety) of “states” in which the central processing units function. The state in which the automation system is functioning is often of no immediate importance to the pilot of an aircraft. However, in order for the human-machine interface to operate correctly, the pilot must be able to identify and have an understanding of the significance of many of the machine states in which the system is operating. These various machine states are often represented to the pilot/operator as “modes” of operation. In the case of confusion or surprise on the part of the pilot resulting from an unexpected of the automation system, the loss of situational awareness can often be more appropriately referred to as a loss of “mode awareness.”<sup>2</sup>

“Modes” within an aviation automation context refers to various navigation and control modes for the aircraft.<sup>3</sup> Sophisticated transport category aircraft are commonly equipped with automation systems that control the lateral navigation (autoflight), vertical navigation (autothrust), and flight management systems (FMS) that act as the human-machine interface. All of these components operate within discreet modes and the pilot/operator has a broad, but limited, ability to control the mode selection. Pilots of these aircraft train extensively in the use of these systems, particularly in the ability to command and recognize the various modes of flight. The need for this training is universally recognized. Although this training has not been standardized within the major airline system, it is far more organized than the situation which currently exists in general aviation. The level of sophistication within general aviation airplanes today in some cases equals that present in highly automated transport category aircraft. The level of training for the operation of these systems is not yet at the same level.

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<sup>2</sup> Wiener, 1989

<sup>3</sup> Mumaw, 2001

The FAA recognized the need for improved training for Technologically Advanced Aircraft (TAA's) in the later part of the 1990's when general aviation aircraft with much modernized digital equipment started to become available. The general aviation community quickly began experiencing the types of new problems associated with technologically advanced systems that had emerged in the transport category aircraft of the previous decade. The FAA's response was the "FITS" (FAA-Industry Training Standards) initiative, a collaboration of the FAA, aircraft and systems manufacturers, the aviation insurance industry and the aviation academic community to provide better training for modern aircraft. FITS emphasized a better understanding of the aircraft's digital systems, scenario-based training, and improved aeronautical decision making. The FITS initiative has been in existence for over a decade and has helped to produce many fine training products. The use of scenario-based training and ground-based simulations has become much more common, not only for TAA's but for all general aviation aircraft. In March, 2010, the NTSB released a special safety study that examined the safety record of light aircraft equipped with "glass-cockpit" technology within the 2002-2008 time period.<sup>4</sup> The study also evaluated light aircraft glass cockpit training requirements. Although it recognized the potential for an improved safety record, the study showed no overall safety improvement for TAA's over that of conventionally equipped aircraft. Citing FITS, the NTSB study pointed out that among the stated goals of the initiative was that of "teaching pilots higher-order thinking skills." However, since the FITS initiative did not (as of today) result in FAA-mandated equipment specific training requirements, pilots have typically relied upon training provided by manufacturers and commercial vendors, resulting in a wide range of initial and recurrent training experiences. It would be safe to assume that the vast majority of the types of training materials available concentrate on standard procedures but do not emphasize a complete understanding of the automation system's structure and logic.

Aviation professionals (and competent amateurs) are familiar with modes of flight. Autopilots, for example, have featured heading, nav, or approach modes for quite a while. Pilots are not, however, in general, familiar with the concept of a "state machine," at least as the term applies to the automation system they have been trained to use in the aircraft. *Herein lies the root of the problem.* In conventional general aviation aircraft navigation and control information is presented to the pilot as "raw data," in the classical configuration of six instruments (the "six pack") that give airspeed, attitude, altitude, turn rate, heading and vertical speed. The pilot is the system integrator. The information presented in a technologically advanced aircraft, while it provides the same information, has already been processed by levels of automated logic. It has already been integrated into the automation system and the pilot is getting "processed" data. In effect, he is not part of the data integration but rather only the recipient of the later stages of the information processing. With added complexity and system capabilities, it becomes increasingly difficult to "inform" the human operator of the logical processes that have preceded the state (or mode) into which the automated system has configured itself. It becomes, in some cases, simply impossible for pilot to remain aware of the state changes occurring within the system. No

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<sup>4</sup> National Transportation Safety Board, 2010

training, short of a study of the low-level software design of the system would be adequate for the user.

With the continuing development of computer-driven automated systems (glass cockpits), multiple components of the aircraft can be finely integrated and managed. In so doing, however, the role of the pilot is reduced to a single component of the complex system. While digital subsystems can be designed with strong feedback loops, the communication channel to the human operators (pilots) will often be quite limited by the degree to which the data can be represented. In actuality, the more complex the automation system, the higher the likelihood that much of the operations are carried out by “machine agents”<sup>5</sup> which are capable of carrying out long sequences of tasks *without user intervention*. The result is an increased difficulty for the user to “see” or recognize a structure to the system. An analytic “scan” of the instruments by the pilot of a conventional aircraft can only be accomplished in an advanced cockpit by “calling” various system interfaces that are often only accessible via a series of “soft button” pushes and/or menu selections. When all operating conditions are normal, and the flight is progressing as expected, this does not create a significant problem. When conditions become abnormal, however, the pilot is suddenly in a position where the sequence of events which led to the present condition is unknown. Even more serious is the possibility that the condition in which the pilot finds the aircraft has been exacerbated by the automation system itself as the system may have already applied several layers of error correction to deal with the originating problem without informing the pilot of these actions.

### Conclusion

Sarter, Woods, and Billings have suggested that pilots of glass cockpit aircraft need to form a “mental model”<sup>6</sup> of the structure present in the aircraft automation. This concept is also reflected in the stated objectives of the original FITS initiative that refer to training techniques that would teach pilots “higher-order thinking skills.” In practice, however, the emphasis found in most of the new, industry-driven training programs for technologically advanced aircraft is on standard operating procedures (SOPs) and scenario-based training. SOP’s and scenario-based training are quite effective in improving the skills of the pilot and, particularly in the case of scenario training, help to improve decision making skills. These are vital elements to any effective training programs. Pilots who are trained in these programs can acquire great skill at operating the on-board automated systems. There is little evidence, however, that they gain a better understanding of the inner structure of those systems – i.e., a better “mental picture” of the complex interactions of the system components. The presence of complex automation systems in the cockpit is driven by a demand for safety and efficiency as well as the market demand for increased aircraft capability. The capabilities of modern general aviation aircraft, at least with respect to on-board avionics, navigation, and datalink capabilities, are today beginning to equal

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<sup>5</sup> Sarter and Woods, 1994

<sup>6</sup> N.B. Sarter, D.D. Woods, and C.E. Billings, Cognitive Systems Engineering Laboratory, The Ohio State University

those of transport category aircraft. Within the air transport industry, automated systems have become the norm and the complexity of those systems continues to grow. Yet, as these systems increase in complexity and autonomous authority, and training efforts are continuous, the incidence of automation surprise remains higher than expected. This is most likely due to the numerous effects of the systems' failures to adequately include the pilot/operator in the decision logic. In this context it will be extremely difficult to design training scenarios which will be effective in reducing the incidence of automation surprise. The most likely outcome will be increased efforts to design into complex systems additional software to monitor, analyze, and create decision trees that attempt to self-correct any detected abnormalities. There is no reason to believe that this same trend will not be demonstrated in general aviation. It is vitally important that the efforts to improve the training for technologically advanced aircraft continue. Better knowledge of system architecture, scenario-based training, and efforts to improve aeronautical decision making should continue to provide great potential for increased safety in general aviation. There is a very great need, however, to find training methods that will help pilots of increasingly sophisticated aircraft gain an understanding of the controlling logic of the digital state machines and agents that are making control decisions for their aircraft. The learning curve will be very steep.

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