Structural Redesign of Pilot Training for Aviation Safety in Automated Aircraft

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Pilots losing flight skills due to overuse of automation has become an increasing industry concern. Recent aircraft accidents have been attributed to pilots' inability to manage their aircraft in manual flight resulting from unexpected changes in automation and loss of situation awareness. While aviation experts have associated these accidents to diminished stick and rudder skills, due to overuse of automation, the problem may be attributed to how pilots are trained in automated aircraft. Lack of understanding more than flight skill loss could be the problem. While the Federal Aviation Administration has encouraged pilots to hand fly to improve skills, limited opportunities for manual flight exist in the current international environment, with potentially less opportunities in the future due to NextGen compliance. To prevent future catastrophic events during this transitional period, a critical view of pilot training will identify how airlines could train pilots in modern day aircraft to maximize safety. The benefit of computer based training to teach operating procedures, fixed based simulators versus level D full flight simulators, redesigning training programs to improve pilots' understanding through cognitive load theory, and the power of repetition will be addressed.

INTRODUCTION

The history of pilot training has been plagued with economic and safety challenges. Loss of equipment and life, combined with operational costs of training pilots in an airplane, encouraged simulator manufacturers to focus on building training devices that would replicate aircraft. With great success, pilot training and checking events moved into a level D full flight simulator (FFS) eliminating the need for an airplane during the training process, notably reducing training expenses while improving safety. This economic advantage saved airlines millions in training costs.

Training curriculums have also changed over the years. A Boeing 727 pilot was required to diagram an electrical system, diagnose malfunctions during flight, and problem solve while hand flying the aircraft. Alternate landing gear was manually extended with a crowbar type lever, a third pilot assisted with systems backup and navigation, and pilots trimmed control surfaces for stability.

Today, that three-person cockpit crew has turned into a two-person flightdeck. Crewmembers who once *flew* round-dial aircraft now *manage* automated aircraft systems. Automated aircraft self-diagnose malfunctions and list procedural steps via computer screens. Pilots no longer attend formal ground schools; they train at home. Alternate landing gear is extended with the flip of a switch, navigation occurs via global positioning systems (GPS), and the aircraft trims itself for coordinated flight.

The job of flying has shifted from skill based to cognitive, but training has not followed suit. While pilots once flew with skill to achieve coordinated flight, today complex aircraft manage coordination with automatic self-trimming features. Likewise, during manual flight automated aircraft have elements of control as a pilot points the airplane in a direction and the aircraft determines the most aerodynamically efficient way to bring about results. With this shift from flying with skill, to management with cognition, *how* pilots are trained and checked should shift too. While airlines are utilizing highly automated simulators, these devices may not be the best tools for the desired outcome of learning automated aircraft.

Due to the reliability of automated aircraft and ease of flying, airlines, in conjunction with Federal Aviation Administration (FAA) programs such as Advanced Qualification Procedures (AQP), have reduced training footprints. While simulators have kept up with emulating aircraft, *how* pilots operate these automated aircraft has shifted to management versus flying, and training has fallen short of operational realism. The economic decision of training reduction has not come without cost. Deficient aircraft management skills with ensuing missed approaches, early configuration changes, and ground mishaps are expensive. Despite insurance, no price can be placed on loss of life.

While advancement in technology has made the flying job easier, mechanization has made the job of learning complex systems more challenging. A shift in pilot training, utilizing appropriate training devices and cognitive based learning techniques, should theoretically improve pilot performance and eliminate future catastrophes and realize improved economies.

The aviation industry is growing rapidly and heading full speed into NextGen, where pilots will be responsible for aircraft separation, perform satellite based landing procedures, and taxi with moving maps. With added complexity and additional tasks, reduced situation awareness (SA) will be open for human error. SA is defined as perception of the environment, understanding the meaning of that experience, and the ability to project that status into the future (Endsley, 2010). The time to redesign pilot training programs is now. Pilots must master current technology via the science of learning, making room in the working memory for additional responsibilities of flying NextGen operations safely.

Note: The author is an Airbus A330 pilot with 28-years airline experience; type rated on the B727, B737, B757, B767, B747-200, B747-400 and A330 aircraft; 22-years instructing in simulators on Boeing aircraft, while flying the line; authored numerous airline flight training program; founder of Aviation Safety International; and currently working on her PhD in aviation, with Embry-Riddle Aeronautical University.

AUTOMATION CHALLENGE REVIEW

Pilot error occurs because pilots are human. Pilot error due to limited knowledge of aircraft operating systems and procedures is inexcusable when cost effective opportunities are available to conduct quality training. In light of current airline crashes, authorities have pointed a finger at pilot skill; however, culpability may belong with pilot training. Air France 447 is a poignant example of a tragic accident attributed to pilot error. Yet, this accident extends far beyond a lapse or miscalculation. Lack of ability and limited knowledge resulted in two pilots pulling the aircraft into an accelerated stall leaving 228 souls in the Atlantic Ocean (BEA, 2012).

Primary challenges addressing airline training include program development and economics. AQP, an alternative to traditional training, has allowed airlines to become creative in training program design, as long as they meet the terminal proficiency objectives (TPOs), thus enabling the airline to reduce the training footprint (Adamski & Doyle, 2005). Safety is of utmost importance. However, management has a fiduciary responsibility to the airline. When safety is measured by the absence of accidents, quantitative data supporting the necessity of improving training is nonexistent.

Current training practices, and tools used, have not kept up with current technology leaving pilots worldwide deficient in knowledge of the aircraft they fly (Dahlstrom, Dekker, van Winsen, & Nycy, 2008). Training programs must be revisited with human factors integrated into how pilots learn, and utilize appropriate training devices with a goal centered learning focus designed to achieve maximum understanding of complex aircraft. Moving into NextGen, it becomes imperative that aviation leaders scrutinize how pilots are trained to operate these complex aircraft in a growingly dynamic airspace, as pilots' workload increases and skies become saturated.

Performance Degradation

Colgan Air 3407 (NTSB, 2010), Air France 447 (BEA, 2012), Asiana 214 (NTSB, 2014a), and UPS 1354 (NTSB, 2014b) had one thing in common—pilot error. These accidents were not isolated human failure events, as 70-90% of aviation accidents are attributed to human error (Airbus, 2007). The underlying premise resulting from these crashes is that pilots are losing their flying skills (Haslbeck et al., 2012). However, what appears to be a simple answer of skill loss may have another explanation due to lack of understanding. A microanalysis of these events may indicate a deeper problem than a lack of pilot skill, but rather limited knowledge of their automated aircraft creating a lack of SA, and an inability to function in critical environments due to an overloaded working memory (Endsley,1995; Maurino, 2000; Wickens, Gordon-Becker, Liu, & Lee, 2004).

Sponsored by the FAA (2013), a working group studied 46 global accidents and major incidents, including 734 U.S. Aviation Safety Reporting System (ASRS) reports, 9155 global Line Operations Safety Audits (LOSA) along with numerous interviews. Results identified a lack of aircraft understanding, overuse of automation, and training concerns, to be among contributing factors.

The possibility that pilots do not understand the aircraft they fly, after having been trained and passing FAA type rating programs in the most advanced simulators is disquieting. Some individuals question if automation has gone too far (Davidson & Barrett, 2011). Perhaps automation has not gone too far, but pilot training has not paralleled technological advancement.

To date, airline training programs are not required to be designed by individuals with human factors experience or knowledge of how people learn (FAA, 2006), and tools being used may not be best suited for comprehensive learning. In addition, training programs may succumb to corporate pressure with economic motivations to shorten the training footprint (Dahlstrom, Dekker, van Winsen, & Nycy, 2008).

The Science of Learning

Working memory. Learning occurs when systems knowledge and procedures move from working memory, where short-term and long-term memory interact, into long-term memory that stores experiences, and become available for recall (Wickens, Gordon-Becker, Liu, & Lee, 2004). Automation challenges begin with natural limitations of working memory and capacity overload due to the large amounts of complex information from highly automated aircraft failing to transfer to long-term memory. Adding to the complexity of cognitive overload, sleep deprivation and mental fatigue further decrease pilot performance (Gonzalez, Best, Healy, Kole, & Bourned, 2011). An overloaded working memory reduces SA (Endsley,1995), and limits a pilots decision making ability.

Historic airline crashes have proven time and again that inclement weather, inoperative systems, and disconnected automation, combined with fatigue, will impose upon an already overloaded working memory (Endsley, 2010), and reduce SA to the point of hull loss. A pilot whose attention is focused on thinking about what button to push may further reduced SA.

Assimilating information. Cognitive Load Theory (CLT) recommends reducing causal factors of overload and structuring information in such a manner that learners are able to formulate thoughts that will assimilate with previous knowledge (Kalyuga, 2009; Paas, Renkl, & Sweller, 2003). Automated aircraft are complex, and the amount of unfamiliar information that must be assimilated is considerable. Restructuring the training program, to allow for phases of training to build upon previous information learned, will aid in reducing overload for better learning and retention.

Creating habits of normal operations by moving procedures from working memory to long-term memory through repetition will create muscle memory and improve long-term performance. Moving standard operating procedures to long-term memory will circumnavigate limitations from a working memory overload (Endsley, 1995).

Power of repetition. Due to AQP and the reliability of automated aircraft, airlines have reduced training footprints and train pilots to proficiency (FAA, 2006). During training, pilots see and perform many procedures once. Once is not enough to create long-term memory storage. Many standard procedures that *are* repeated require *more* repetition for memory formation, especially for pilots on reserve with minimal, or no, opportunity to reinforce lessons learned. Moving standard operating procedures to long-term memory will free the working memory for current demand issues when the unexpected occurs. Repetition is the answer to success in operational procedures and performance in complex aircraft.

The intent of AQP is to integrate training and evaluation, and train pilots to proficiency (Adamski & Doyle, 2005). Yet, the concept has shifted to a philosophy of reducing training footprints to avoid overtraining all pilots, and provide additional training for those who fail. This practice, however, may also reduce the quality of learning for those pilots who successfully navigate the shortened footprint. *Overlearning* is never wasted as it enhances speed and accuracy, and leads to automaticity (Wickens et al., 2004).

Automaticity is essential for airline pilots and improves SA (Endsley, 2010). A pilot who executes a missed approach, responds to a Traffic Collision Avoidance System (TCAS) warning, or performs a windshear escape maneuver, must have both speed and accuracy available for performance, without thinking about operational steps. Under these circumstances, pilots with available working memory (due to automaticity and understanding) will improve decision making. Pilots with automaticity and a free working memory will also have superior aircraft management skills, with less chance of exceeding aircraft limitations and operational constraints, and will create a safer operation than those with an overloaded working memory.

The operational challenges of long-haul pilots, combined with the complexity of automated aircraft, make it all the more imperative to create a level of automaticity with standard operating procedures. Repetition is fundamental to improving performance and can be achieved through a theoretical and structural redesign of how pilots are trained in automated aircraft.

Lack of Understanding

The Air France 447 accident was attributed to the pilots' inability to fly their plane without automation and instrument loss (BEA, 2012). However, the pilots' lack of understanding of the Airbus A330, due to higher cognitive demands, may have been the underlying problem. The pilots' reactions, inactions, and behaviors brought down that Airbus as they did not understand their equipment, available resources, and how to manage the plane when automation failure occurred at altitude, and pulled the aircraft into a stall (Palmer, 2013). Distraction due to lack of systems knowledge can also undermine SA.

Degani, Barshi, and Shafto (2013) analyzed Air Transat Flight 236—an Airbus A330 that experienced a dual engine flameout due to a fuel leak. The first indication of a problem was low oil temperature, low oil quantity and high oil pressure. Confused and distracted by the oil issue, the pilots first noticed a fuel leak with a 3,000-pound fuel imbalance warning. Startled, the crew performed a balancing procedure from memory, forgetting to check the fuel prior to opening crossfeed valves, as directed per the procedure, and proceeded to dump the remaining fuel out the leak from within the engine.

Degani, Barshi, and Shafto (2013) blamed the aircraft, attributing the absence of integrated information with engine and fuel parameters, missing indications from traditional planes such as a yoke tilt with fuel out of balance, and purported that fuel available at *each* waypoint was hidden within the computer, to be contributing factors. In defense of the aircraft, if these pilots had an understanding of the aircraft systems, confusion with low oil temperature and high oil pressure may have been a non-event, and led the pilots to investigate the fuel flowing into (and out of) the problematic engine.

There was a time pilots understood the fuel oil heat exchanger and the relation of fuel and oil within an engine. As a side effect to automated aircraft self-reporting malfunctions on the Engine Indication and Crew Alerting System (EICAS), pilots no longer have in-depth aircraft knowledge. In addition, total fuel on the Airbus A330 is *always* displayed in the pilots' view—these pilots should have seen a discrepancy and questioned the missing 3,000-pounds of fuel. Instead, a fuel out of balance alert startled the pilots into reaction. The crew performed a procedure by rote, neglecting to look at total fuel, and without understanding the connection of oil and fuel. Repetition to learn standard operating procedures, and an in-depth understanding of the aircraft, are disparate from rote memorization. The crew's lack of understanding and reaction caused them to turn their highly automated plane into a glider, not the lack of system display integration. The question must be asked if pilot training (initial and recurrent) could better prepare pilots for the unexpected.

Rote memorization is not the answer to training, as it leaves pilots with minimal understanding that may not transfer to situations outside those practiced, and expected, during training and checking events (Casner, Geven, &Williams, 2013). Pilots trained to memorize abnormal operational procedures who are then tested, aware the event is about to occur, will show higher proficiency due to expectation of the planned event. However, that does not mean proficiency will transfer to the flight line when the pilot is fatigued, stressed, and faced with the unexpected.

Casner et al. (2013) tested pilots on performance with anticipated maneuvers against *surprise* abnormal events. Results indicated that pilots had more difficultly with unexpected events than anticipated events. If operational understanding has not moved to long-term memory, the pilot will become overloaded during surprise events such as AF447. Current training practices utilizing rote memorization, with an anticipated-event approach, in scenario-based training may not adequately prepare pilots for unanticipated events during flight operations.

Confidence and Competence

To explore this issue, an interview was conducted presenting a series of questions concerning overall pilot performance and current training practices with five Airbus A330 subject matter experts (check airman, instructors and FAA designees); three central themes emerged—lack of systems understanding; poor aircraft management; pilots rarely flew without automation (and never without the use of a flight director). When a line check airman for an international airline was asked why Airbus A330 pilots did disengage the automation, he stated, "Pilots never hand-fly and practice because of a lack of confidence, lack of proficiency, and fear" (check airman, personal communication, February 12, 2015).

In order to learn pilots must not only have aptitude, but also have the ability to practice through repetition (English & Visser, 2014), receive feedback (Hattie & Timperley, 2007), and feel confident (Johnson, & Fowler, 2011) that the level of performance they achieve will ensure a safe operation. Without repetition of a continued set of successful attempts, doubt will prevail leaving the pilot with reduced confidence.

Stress and confidence impact SA. Cuevas (2003) described factors that may have an impact on operational performance to include skill, experience, and personality traits associated with how individuals deal with stress. The pilot personality is one that exudes confidence. Due to this greater confidence level, pilots can deal more effectively with higher amounts of stress. Confidence also correlates with competence and may be a contributing factor to success in both training and flight line operational safety (Johnson, & Fowler, 2011).

To explore the confidence level of pilots, after pilot training completion, the author queried fellow Airbus pilots. Thirty-five, out of 38, of these pilots claimed they had never felt more unprepared with less confidence prior to their initial A330 checkride than in any other aircraft they had flown. A few of these pilots requested additional training in order to feel more comfortable, but were denied and assured they were on par with performance. Many Airbus pilots state it takes two or three years to feel confident with the plane. However, the moment a pilot leaves training in an automated aircraft, that is the highest level of systems knowledge and proficiency with abnormal operations they will achieve due to automation and reliability. Ensuing confidence does not occur from additional learning and increased performance over the years of operation, but from the realization the pilot can function with minimal knowledge due to automation. The challenge begins when the automation fails.

Based on the author's experience, and interviews with subject matter experts, training on the Airbus A330 is a challenge due to aircraft complexity and time afforded to training. From the pilots' perspective, there is much to learn in a short time and they retain only what it takes to get by in the moment. This reality leaves pilots with less knowledge and confidence than experienced on other aircraft. Increased stress, decreased SA, and potential error are common among pilots new to automated aircraft. While experience enhances SA in the operational environment, experience of managing an automated aircraft, despite thousands of flight hours, does not increase knowledge of the aircraft nor improve performance when the unexpected occurs (Casner et al., 2013). When the environment changes and pilots do not have core knowledge of their aircraft, problems arise, as was witnessed with the previously cited airline crashes (BEA, 2012; NTSB, 2010; NTSB, 2012; NTSB, 2014). Training personnel must refocus their goal from one of pushing a product to the flight line, to creating competent and confident pilots through quality training, ensuring knowledge retention, utilizing the right tools.

The Right Tools

Computer based training (CBT). Utilizing CBT for greater interaction with flight operations, in addition to systems training, to create mode awareness, perform flightdeck set up, and flight management computer operation, will assist pilots in storing vital pieces of data into long-term memory. Enabling pilots to utilize CBT at home will provide flexibility to the individual learner, as well as cost effectiveness to the airline. Rapid identification and understanding of systems and concepts will improve SA and allow pilots to use working memory for abnormal operations.

Many airlines have shifted to an at-home *systems* training program. By adding flightdeck setup, mode awareness, and navigation to systems CBT, airlines could provide optimal environments to maximize learning prior to the student arriving at the training center. Utilizing CBT to learn systems, aircraft modes, and navigation, will aid in understanding the automated aircraft. Once procedures have been moved to long-term memory with adequate retrieval connections, the pilot will have improved SA with an added level of safety realized, and be prepared for the next phase of training.

Fixed base simulator (FBS). A level 6 FBS replicates the level D FFS, but without motion, and could be utilized for pilots during the training process to provide better understanding while saving airlines millions. Since the Airbus A330 is managed versus flown, any training conducted on an autopilot in FFS is a waste of resources. A level 6 FBS will enable pilots to practice what they learned via CBT and experience opportunities to build associative patterns through cost effective repetition.

Many airlines utilize a flight training device (FTD) as a segment of training prior to FFS training. A level 6 FBS is a FTD—one that emulates a level D FFS, but without the motion and high fidelity visual. Under the construct of quality training, and the intent of this paper, the level 6 FBS is the only FTD recommended in lieu of a FFS. The difference from an old technology FTD to the new technology of a level 6 FBS is functionality enabling a level 6 FBS to mirror the level D FFS, but without motion.

Full flight simulator (FFS). A critical view is paramount as to the necessity of a level D FFS while training pilots to fly advanced automated aircraft. A level D FFS mirrors the aircraft they replicate. However, these training devices might not be the best tools for pilot training on the A330—an aircraft that provides no feel in the stick, no stick-shaker, and where pilots do not trim control forces. Feedback on the A330 comes in the form of visual displays. Any training flown with automation connected is unnecessary in a level D FFS.

High operating costs of level D FFS have not only reduced availability for practice, but have incentivized airlines to shorten training footprints. Shifting from a level D FFS to a level 6 FBS not only has economic benefits, but will also provide opportunities to reduce cognitive load and make available increased cycles of repetition in order to create a level of automaticity that is missing in current training programs. In addition, while the FAA (2015) requires upset recovery training to be performed in a level D FFS, due to the unusual attitudes and the constraints of hydraulic legs, this training can *only* be conducted in a FBS. Moving training events from a FFS to a level 6 FBS will also remove the added distractions of unnecessary motion and enable pilots to perform operations in a cost effective manner.

Motion versus Non Motion

Go et al. (2003), in conjunction with the FAA, conducted a quasi-transfer experiment utilizing a Boeing 747-400 simulator to determine the necessity of motion in simulators for complex aircraft. Results indicate that pilots trained without motion outperformed those with motion in both training and transfer to the aircraft, with less effort and more precision. The utilization of a thirty million dollar machine with high operational costs must be questioned, when training in a level 6 FBS could be accomplished better, at less than three million dollars, with minimal operational costs.

Manual Flying

Aircraft design, automation, and current international operations have minimized opportunities for pilots to manually fly their aircraft. NextGen might eliminate those opportunities all together due to operational constraints. While most airline pilots would not have a problem manually flying the aircraft, fatigued with reduced reaction time, the challenge becomes an overload on the pilot monitoring (PM) with reduction in backup reinforcement. When the pilot flying (PF) disconnects automation, the PM is required to communicate with ATC, often with a language barrier of foreign controllers, between multiple radio transmissions in the traffic area, and program changes into the flight management computer. The PM may become overloaded with an increased potential of making errors. The PF, who was once a level of support and shared the operational load with the PM, is taken out of the loop with concentration focused on flying the plane, providing (at best) partial attention to confirm accuracy in programming, frequency changes, and SA.

Utilizing automation is the safest course of action, under most circumstances, during line flying due to the extra level of backup that enables greater SA for both pilots. However, pilots must retain flying skills for when the automation fails. The retention of flight skills should be retained in a level D FFS, not on the flight line.

Airbus recently developed a new way of training pilots to fly their A350, requiring pilots to become proficient at hand-flying before turning the automation on (Pasztor, 2014). While the concept of hand flying is strong, learning must come first.

For optimum learning to occur, systems, displays, aircraft mode functionality, and flight management computer operation should be conducted in a CBT, followed by procedural and abnormal training in an FBS, then transferred to a level D FFS to hand fly the device that was designed to replicate the aircraft in performance. Learning to physically manipulate the aircraft must be tied to understanding displays and system functionality.

A Shift in A330 Training and Checking

The International Pilot Training Consortium (IPTC) was formed with intent to find a solution via pilot training for modern aircraft (Learmount, 2014). The IPTC, comprised of the International Civil Aviation Organization (ICAO), International Air Transport Association (IATA), International Federation of Airline Pilots (IFALPA), Royal Aeronautical Society (RAeS) and International Coordinating Council of Aerospace Industries Associations (ICCAIA), has created awareness, but a solution has yet to be found. The solution could be as simple as taking a step back to view the big picture, with a simple redesign of training methodologies. AQP requires training to bear operational realism to flight operations, *match* pilot experience, and demands the most relevant training device to be utilized (Longridge, 2001).

Match experience. In the United States, due to seniority issues with the Airbus A330 and other long-haul, higher paying aircraft, operations are often subject to more experienced pilots. This higher level of experience could be utilized to create more airline efficiencies, and adapted to the A330 training footprint. Pilots with international experience should utilize training events to learn the new aircraft. Time spent receiving appropriate feedback to store operational procedures into long-term memory, rather than simulated flight to airports they have previously experienced, could prove valuable. The intent of AQP was to improve safety and save training costs utilizing experience, not to shorten the length of training for all pilots.

Operational realism. The most relevant device for learning the automated aircraft is an FBS. Automated aircraft diagnose malfunctions and list appropriate action items to configure the plane per malfunction. An experienced pilot should be able to read and perform a checklist without a level D simulator. Thus, training events that once occurred in round-dial aircraft prior to the EICAS, and have zero impact on performance and landing characteristics, should be viewed as unnecessary events with time better spent on repetition of standard operations. There is no logical reason to conduct any training in a level D FFS that will be performed with an autopilot engaged, when a level 6 FBS is available.

Knowledge assessment. Systems knowledge is essential in operating automated aircraft. Another challenge with AQP is a change in assessment of pilots' knowledge. Pilots pass an electronic test and are allowed to continue forward with training. However, answering test questions via a computer does not necessarily indicate a level of understanding, despite the grade. Airline training management should reconsider reviving the requirement of an operational, performance-based oral examination with a qualified training examiner, prior to flight training and being released to the flight line to assure operational understanding.

Recurrent training. Due to the nature of long-haul flying, and the reserve system at many airlines, pilots may go many months, or years, without a takeoff or landing in the actual aircraft. Also, many pilots may not see the inside of an aircraft for equally as long. No time limit exists that a pilot may be out of the aircraft and remain current. While the FAA requires three takeoffs and landings in 90 days, which may be conducted in the simulator as a recency, the question must be asked if this process is appropriate to remain proficient in an automated aircraft, with an adequate level of understanding for competency, when failures occur.

Casner, Geven, Recker, and Schooler (2014) conducted a study in a Boeing 747-400 simulator to ascertain flight skill retention in an automated aircraft. While *rusty*, flight skills remained relatively intact without consistent practice. Whereas degradation of cognitive ability to recall procedures, remember completed steps, visualize aircraft position, perform mental math computations, or recognize *abnormal situations,* was apparent without consistent practice (Casner, Geven, Recker, & Schooler, 2014). The pilots on Flight 236 flamed out both engines due to lack of understanding, but the ability to fly the plane without operating engines was evident.

Recurrent training programs, and recency events, should incorporate flightdeck setup, taxi, takeoff, and landing procedures in addition to three landings. All phases of flight could be effectively accomplished in the at-home CBT training module designed for initial pilots, cross-utilizing resources. When pilots arrive to the training facility, they should demonstrate proficiency in all phases of flight and receive three takeoffs and landings in the FBS with automation engaged. The pilots should then transition to the level D simulator to fly the aircraft without the autopilot for two circuits, including a missed approach to a final landing.

CONCLUSION

NextGen is designed for safer practices, reduced workload, and improved operational systems worldwide (Darr, Ricks, & Lemos, 2010). However, if core aircraft operating procedures are not solidified in a pilot's long-term memory, the added complexity associated with NextGen could create yet another opportunity to overload the pilot's working memory leading to future catastrophes. The link connecting SA to performance, and performance to training is strong. Inadequate SA has been attributed to 52% of all accidents (Airbus, 2007).

Training must shift focus from memorizing procedural steps to assisting pilots with understanding aircraft performance characteristics in different configurations, improve mental models of systems and information available via instrument displays, and train pilots how to think by taking control of their aircraft (even while the automation is connected) in order to improve SA. Managing an automated aircraft should be conducted via standard operating procedures for flightdeck setup, and normal operations. However, understanding modes, systems, and technology is critical for safe management of complex aircraft when the unexpected occurs.

Advanced technology designed to reduce workload and improve SA has created challenges of complacency, automation dependency, and reduced SA due to aircraft complexity and lack of understanding. With the continued growth of technology and NextGen on the horizon, pilots will be responsible for aircraft separation, perform satellite based landing procedures, and taxi with moving maps—additional challenges that necessitate improved SA.

The industry must change how it thinks about training and focus on the concept of learning. Increased performance and improved SA, prior to the added distraction of NextGen, must be addressed. By training differently, accommodating how individuals learn, and taking into account aircraft complexity, training programs could create a better product with reduced training expenses. A training program redesign, utilizing CBT more extensively, and a level 6 FBS could prove financially viable with operational superiority for training pilots.

Managing automated aircraft safely can be realized through improved understanding of systems, equipment, and modes of operation. Updating how airlines train pilots will afford higher levels of SA that will transfer to the aircraft with improved performance resulting in safer operations at minimal expense. Utilizing the correct device for pilot training will create superior and more competent pilots with greater confidence. Maximizing CBT and FBS for learning, while utilizing the FFS for manual flying, will reduce the cost of initial and recurrent training expenses, and improve pilot performance.

Current challenges include breaking an archaic paradigm of training philosophies, and the financial impact to FFS manufacturers, who may fight the low cost of FBS technology. However, the overall goal must be safety focused while safekeeping airline economics to keep the aviation system thriving. Future research is open to testing the feasibility of increasing CBT parameters, shifting flight training from a level D FFS into a level 6 FBS for quality learning, and increasing the training requirements, including CBT for recency and recurrent training.

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