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WHAT SAFETY INITIATIVES HAVE BEEN INTRODUCED IN RESPONSE TO GLASS COCKPITS IN GENERAL AVIATION

By

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Bachelor Aviation Management, Southern Illinois University, 2011

A Research Paper

Submitted in Partial Fulfillment of the Requirements for the

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WHAT AVIATION SAFETY INITIATIVES HAVE BEEN INTRODUCED IN RESPONSE TO GLASS COCKPITS IN GENERAL AVIATION?

By

Sara L. Sorrill

A Research Paper Submitted in Partial

Fulfillment of the Requirements

For the Degree of

Public Administration

in the field of Aviation

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TITLE: WHAT AVIATION SAFETY INITIATIVES HAVE BEEN INTRODUCED IN RESPONSE TO GLASS COCKPITS IN GENERAL AVIATION?

MAJOR PROFESSOR: Dr. David NewMyer

With any new technology in aviation come new regulations, policies and concerns about safety related to the implementation of this new technology. The purpose of this research is to explain what aviation safety initiatives have been introduced in response to the use of glass cockpits in general aviation. The method that will be used to explore this topic and answer this question will be a literature review of already published information on glass cockpits. This information will be taken from aviation-related articles, reports, studies and websites. Discussion about policy changes that have been developed due to the introduction and continued use of glass cockpit technology will be explained, including studies completed by aviation organizations to compare this technology to conventional aviation cockpit panels and their results. Studies show that training is an important factor to this topic. Increased training means more time and more money will need to be put forth by those learning to fly and teaching to fly, as well as by those building and bettering aviation technologies, all in order to continue to make flight a possibility.

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CHAPTER 1

INTRODUCTION

The purpose of this research paper is to address the topic what aviation safety initiatives have been introduced in response to glass cockpits in general aviation. This research will explain how safety has been impacted by the use of glass cockpits and how U. S. aviation initiatives have been introduced or should be introduced to today's general aviation industry.

This topic is important because the use of glass cockpits has grown significantly. "Technically Advanced Aircraft (TAA) are equipped with new generation avionics that take full advantage of computing power and modern navigational aids to improve in-cockpit information about traffic, weather, airspace and terrain" (Aircraft Owner and Pilots Association, 2012). TAAs are entering the general aviation fleet in large numbers. "There are three categories of TAA aircraft which are, newly designed aircraft, newly manufactured classic design aircraft equipped with new avionics and retrofitted existing aircraft of varying ages" (Aviation Today, 2007). "Today, nearly all newly manufactured piston-powered light airplanes are equipped with digital primary flight displays. The number of older airplanes being retrofitted with these systems continues to grow" (National Transportation Safety Board, 2010). "In a safety study conducted by the AOPA between 2003 and 2006, TAA accounted for 2.8 percent of the General Aviation aircraft fleet" (Aviation Today, 2007).

The method that will be used to explore this topic and answer the question of, what aviation safety initiatives have been introduced in response to the use of glass cockpits in general aviation, will be a literature review of already published information on glass cockpits. This information will be taken from aviation related articles, reports, studies and websites. Discussion about policy changes that have been developed due to the introduction and continued use of glass cockpit technology will be explained, including studies conducted by aviation organizations to compare this technology to conventional aviation cockpit panels and their results.

Therefore, this research paper will address the following research question, what aviation safety initiatives have been introduced in response to the use of glass cockpits in general aviation? The discussion of this question will seek to determine if new aviation initiatives or the changes in current initiatives will successfully improve aviation safety with regard to the use of glass cockpits in general aviation.

CHAPTER 2

BACKGROUND ON GLASS COCKPITS

“General aviation is defined as the operation of civilian aircraft for purposes other than commercial passenger transport, including personal, business, and instructional flying” (Answers, 2012). Some examples of general aviation are “private and sport flying, aerial photography and surveying, crop-dusting, business flying, medical evacuation, flight training, and the police and fire fighting uses of aircraft. The airplanes used in general aviation range from small, single-engine, fabric-covered aircraft to multi-million dollar business jets. General aviation is providing a viable air transportation complement to the air carrier hub and spoke system. Hub and spoke is a term used in the air transportation world to describe a common method for an airline to organize their flights. Airlines will have hubs in a few cities where most of their flights will originate, with spokes out to non-hub cities. When flying from one city to another, passengers will usually have a connecting flight through one of the airline's hubs. This system can also be implemented with other forms of transportation such as train, truck or boat” (Bednarek, 2012).

“The success of the NASA-led glass cockpit work is reflected in the total acceptance of electronic flight displays beginning with the introduction of the Boeing 767 in 1982. Airlines and their passengers have benefited from their adoption” (National Transportation Safety Board, 2010). Glass cockpit airplanes have been turning up everywhere over the past 10 years. This technology was first used and developed for military, commercial aircraft applications in the 1960’s and 1970’s. Glass cockpit avionics first started to appear in light aircraft as non-certified systems installed in experimental and amateur-built aircraft (National Transportation Safety Board, 2010).

A glass cockpit is an aircraft cockpit equipped with large computerized screens that display flight information. The information displayed may include satellite weather, synthetic vision, infrared vision, terrain awareness information, traffic information, and moving maps. “Glass cockpits are supposed to help improve the pilot's situational awareness” (Aircraft Owner and Pilots Association, 2012). Flight Management Systems (FMS) are intended to help monitor and control the aircraft. FMS technology has largely replaced the numerous instruments in an analog cockpit. It offers an increase in automation ability and integration of controls that are often far more than regular analog aircraft accurate (Aviation Knowledge, 2011).

The revolution in cockpit design is a combination of both opportunity and necessity. “Those working to advance commercial airline passenger service thought of it first. Prior to the 1970s, air transport operations were not considered sufficiently demanding to require advanced equipment like electronic flight displays. The increasing complexity of transport aircraft, the creation of digital systems and the growing air traffic congestion around airports began to change that” (Langley Research Center, 2000).

The Experimental Aircraft Association (EAA) is a general aviation nonprofit association dedicated to active participation in aviation. Lane Wallace is an internationally known columnist, writer, editor, and author, according to the EAA. In her book Airborne Trailblazer: Two Decades with NASA Langley's 737 Flying Laboratory, she writes that “the average transport aircraft in the mid-1970s had more than 100 cockpit instruments and controls, and the primary flight instruments were already crowded with indicators, crossbars, and symbols" (Wallace, 2012). The growing number of cockpit elements was competing for cockpit space and pilot attention. "What was needed were displays that could process the raw aircraft system data and flight data into an integrated, easily understood picture of the aircraft situation, position and progress, not only in horizontal and vertical dimensions, but with regard to time and speed" (Wallace, 2012).

Engineers at NASA (National Aeronautics and Space Administration) Langley Research Center worked with key industry partners to develop and test electronic flight display concepts, to include an all-important series of flights to demonstrate a full glass cockpit system (Langley Research Center, 2000). In designing the experimental system, the information pilots needed to have and how it should be presented to them had to be considered. The information should be presented in such a way that the pilots could easily manage their flight workload without getting confused and still safely fly the aircraft. This would be accomplished by having displays that could process the raw aircraft system and flight data into an integrated, easily understood picture of the aircraft situation, position and progress, not only in horizontal and vertical dimensions, but also with regard to time and speed. According to NASA, the result was a glass cockpit system, equipped with an autopilot, that increased safety by reducing pilot workload at peak times and assisting the pilot maintain situational awareness (Langley Research Center, 2000).

The success of the NASA-led glass cockpit work is reflected in the acceptance of electronic flight displays by commercial air carriers and the aviation industry as a whole, beginning with the introduction of the Boeing 767 in 1982 (Langley Research Center, 2010). Glass cockpit technology was once reserved for airline and military flight crews. Today, general aviation aircraft also use this technology. The Department of Defense adopted glass cockpit technology in the 1970's in order to increase the performance of its newest aircraft such as fighter-interceptors and long-range bombers (Langley Research Center, 2000).

CHAPTER 3

GENERAL AVIATION GLASS COCKPIT SYSTEMS

"Garmin's G1000 is an all-glass avionics suite designed for installation on a wide range of business aircraft and general aviation. Garmin introduced the G1000 in the first quarter of 2004 in the twin engine DA42 Twin Star and the DA40-180 Diamond Star aircraft" (Garmin, 2003). It is a seamlessly integrated package that makes flight information easier to scan and process. G1000's revolutionary design brings new levels of simplicity to the cockpit. The G1000 puts a wealth of critical flight data at the pilot's fingertips. Its glass flight screen presents flight instrumentation, navigation, weather, terrain, traffic and engine data on large-format, high-resolution displays. "The G1000 replaces traditional mechanical flight instruments with Garmin's GRS 77 Attitude and Heading Reference System (AHRS)" (Garmin, 2012). The integrity and reliability of the AHRS and generated attitude outputs are due to the cross checks of all the attitude information in the G1000 subsystems making it quicker for the AHRS to identify a sensor failure that could lead to potential Hazardous and Misleading Information (HMI)" (Cessna, n.d.). AHRS provides accurate, digital output and referencing of the aircraft position, rate, vector and acceleration data. AHRA can restart and properly reference itself while the aircraft is moving (Garmin, 2012).

"Garmin's G3000 was introduced for technical standard orders (TSO) certification in the second half of 2011 but was produced and named in 2009" (Marsh, 2009). "A TSO is a minimum performance standard for specified materials, parts, and appliances used on civil aircraft. G3000 entered the aircraft fleet in 2012. Honda Aircraft was the first manufacturer to announce and demonstrate plans for a new configuration on the Garmin G3000 Primary Flight Displays for the Honda Jet. This enhancement provides pilots a more user-friendly visual scan of additional flight information in a concise format that contributes to improved situational awareness and safety" (Honda Jet, 2012). The pilot or co-pilot can select and see more information within an area that uses a wide and high-resolution display. "This new digital avionics revolutionizes the interface between pilots and their electronics by streamlining menu structures" (Garmin, 2012). The G3000 eliminates visual clutter, replacing mechanical knobs, buttons and selector switches. By centralizing data entry in one easy to access location, the Garmin G3000 attempts to give pilots more focused control with less motion and effort. The new glass touch screen controller serves as a primary point of entry for the G3000 system. Featuring a desktop-style, icon-driven interface built on a new shallow menu structure, the system enables pilots to access more systems and sensors with fewer keystrokes and page sequences. Its user interface is totally software based. Garmin describes the G3000 to be easily configured for specific airframes and avionics configurations. The future enhancements, applications and system growth capabilities can be readily accommodated without physically altering the mechanical controls (Garmin, 2012).

CHAPTER 4

GENERAL AVIATION GLASS COCKPIT STUDIES

“The General Aviation Technically Advanced Aircraft (TAA) Safety Study in 2003 identified several accidents attributed to the fact that the pilots were not familiar with the technology available to them in their aircraft. Pilot age, certificate level and pilot rating are all considered important factors” when completing safety studies. One particular study was conducted by the NTSB was designed to identify differences in safety between conventional aircraft and glass cockpit aircraft” (National Transportation Safety Board, 2010). Three different areas were looked at. The study “analyzed manufacturer records, aircraft investigation information, and activity survey data was looked at to compare the accident experience of recently manufactured light single-engine airplanes equipped and not equipped with glass cockpit displays. An evaluation of glass cockpit training requirements and resources was conducted to characterize the training and to identify areas for potential safety improvement. Accident cases were reviewed to identify emergency safety issues associated with the introduction of glass cockpit displays into this class of aircraft” (National Transportation Safety Board, 2010).

“The goal of one study conducted by the NTSB was to identify differences in operational characteristics of glass and non-glass aircraft and determine how glass cockpits have affected safety. The NTSB compared accident information and activity between glass cockpit aircraft and conventional aircraft manufactured between 2002 and 2006” (National Transportation Safety Board, 2010). They wanted to answer three questions. Has the introduction of glass cockpits made general aviation safer? Has the general aviation industry been properly prepared for the introduction of glass cockpit technology? What have we learned from the case studies of light aircraft glass cockpit accidents (Kolly, p. 8)?

One study conducted by the FAA in 2003 compared three topics**.** The first area was accident information, second aircraft activity and third, the accident rates. “It has been reported that glass cockpits have twice the fatal accident rate when compared to aircraft with traditional cockpits using steam gauge analog instruments, prompting calls for better training and error reporting. Steam gauge is an old fashioned nickname for the analog instruments that were common in airplanes dating back to the early days of aviation and still found in some airplanes today. The nickname comes from the big temperature and pressure indicators found in early steam powered railroad locomotives. A glass cockpit airplane may still have steam gauges as backup, but the primary instruments are shown on electronic displays” (Airport Chronicles, 2010).

“Of the 266 total accidents looked at, conventional aircraft had 141 accidents with 23 (16%) of them being fatal. Of the 125 accidents involving glass cockpit aircraft, 39 (31%) of those were fatal” (Tresscot, 2010). The flight data revealed that general aviation accidents associated with glass cockpits occurred more during flight phases such as climb, cruise and approach and more loss of control in flight with collision of terrain and weather encounters (Kolly, p. 20). These situations take place while in flight, which could explain why a larger number and percentage of accidents are fatal.

The results show that the conventional aircraft had a “majority of incidents on the ground prior to take off or during landing. Conventionally equipped aircraft generally had accidents in the takeoff, approach, and landing phases, while glass cockpit aircraft accidents typically occurred in climb, cruise, and approach. Of the accidents in glass-equipped aircraft, many involved loss of control, flight into terrain, and encounters with weather. Glass cockpit crashes are typically linked to business or personal flights while conventional cockpit crashes were more likely to be used in training" (National Transportation Safety Board, 2010). This study did not show a safety benefit for glass cockpits during the studied period (Kolly, p. 25). It found that there are very large differences in the way glass and non-glass aircraft are used. The Board found that glass cockpit aircraft were more likely to be used for business and personal flying and to be flown IFR (Instrument Flight Rules) by older pilots. "Instrument flight rules are regulations that govern flying when weather conditions are below the minimum for visual flight rules. Non-glass airplanes had a significantly higher percentage of takeoff and landing accidents, but were more likely to be used for instruction and were flown on shorter flights" (Tresscot, 2010). This particular study looked at accident rates based on the different uses of the aircraft.

A 2005 analysis by the AOPA Air Safety Foundation came to a conclusion much like a previous study conducted by the FAA in 2003. "The General Aviation Technically Advanced Aircraft (TAA) Safety Study of 2003 identified several accidents attributed to the fact that the pilots were not familiar with the technology available to them in their aircraft" (Craig, 2003, p. 1). The report attributed most accidents to faulty pilot judgment rather than problems with the avionics or the pilot aircraft interface (National Transportation Safety Board, 2010). The pilot aircraft interface is a means through which the pilot receives information and controls or communicates with the aircraft and the environment. "Of the accidents, those TAA with glass cockpits, aircraft had a smaller percentage of total accidents but a larger percentage of fatal accidents" (National Transportation Safety Board, 2010).

The increasing number of TAAs enabled the Aircraft Owner and Pilots Association Air Safety Institute's study, which included 20,000 certified piston-engine airplanes delivered between 1996 and 2010 by seven leading airplane manufacturers. "Under half were equipped with conventional instruments. Almost all of them were built before 2006" (Aircraft Owner and Pilots Association Air Safety Institute, 2012). The AOPA ASI released the Accident Record of TAAs. According to the study, the report concluded that the introduction of TAAs had not decreased accident rates, as some expected to happen. In fact, newer glass cockpit airplanes had demonstrably higher rates of accidents during takeoffs, landings and go-arounds" (Bergqvist, 2012).

The airplanes studied included approximately equal numbers of glass cockpit aircraft and non-glass cockpit aircraft which would total approximately 40,000 aircraft. The study found that the accident rate varied between different categories of airplanes, but found differences between analog and glass cockpits were minimal. Differences between aircraft categories partly reflected underlying differences in flight conditions and the types of flying done. In all three categories, glass-panel aircraft suffered demonstrably higher rates of accidents during takeoffs, landings, and go-around (Aircraft Owner and Pilots Association Air Safety Institute, 2012). The "most dramatic differences in the accident record were between three distinct groups of aircraft which were single-engine fixed-gear models, complex or high-performance models and accident rate for models certified since 1998" (Aircraft Owner and Pilots Association Air Safety Institute, 2012). The study's authors reached no conclusion as to why landing or takeoff accidents would be greater with TAAs (Bergqvist, 2012). The findings of these studies along with suggestions are given to the Federal Aviation Administration so that regulatory improvements can be made in an attempt to improve safety.

CHAPTER 5

IMPACT OF GLASS AVIONICS ON OVERALL SAFETY

Robert Littlefield writes in his book that "glass cockpit technology offers general aviation pilots the promise of increased levels of safety and performance" (Littlefield, 2011). There are many safety concerns when discussing aircraft built with glass cockpits. Placing a general aviation pilot directly into such a sophisticated cockpit has many worried. Those that are concerned include flight instructors, air traffic controllers as well as other pilots that must fly in the same sky. There have been cases where pilots have become confused by computer generated messages. "One specific accident where this was a problem in the air was during Air France Flight 447 in July 2012. Investigators determined that a combination of technical failures and mistakes made by the inadequately trained pilots was responsible for the crash. Pilots seemed to have trouble looking past the automation they were accustomed to and not really able to continue with the old raw information that pilots used to depend on" (Hosford, 2012).

There have been several recent accidents where it is clear that the pilots were unsure of what the aircraft systems were doing, and as a result, took incorrect corrective actions. The accident at Nagoya, Japan is an example of this. In this case, the pilots engaged in actions that contradicted the logic of the autopilot. Not realizing the effects of their efforts, they were unable to take the correct actions, and ultimately lost control of the aircraft. This was a clear case of mode confusion.

According to the accident investigation report, China Airlines Airbus Industrie took off from Taipei International Airport on April 26, 1994 and continued flying according to its flight plan. While approaching Nagoya Airport for landing, the aircraft crashed into the landing zone close to the taxiway of the airport. While the aircraft was making an ILS approach to Nagoya Airport, under manual control, inadvertently activated the GO lever, which changed the Flight Director to GO AROUND mode and caused a thrust increase. This made the aircraft deviate above its normal glide path. The APs were subsequently engaged, with GO AROUND mode still engaged. Under these conditions the F/O continued pushing the control wheel in accordance with the CAP's instructions. As a result of this, the THS (Horizontal Stabilizer) moved to its full nose-up position and caused an abnormal out-of-trim situation. The crew continued approach, unaware of the abnormal situation. The AOA increased the Alpha Floor function was activated and the pitch angle increased. It is considered that, at this time, the CAP who had taken the controls, judged that landing would be difficult and opted for go-around. The aircraft began to climb steeply with a high pitch angle attitude. The CAP and the F/O did not carry out an effective recovery operation, and the aircraft stalled and crashed (Nagoya, 1994).

Due to the nature of the integration of the information, if there is an electronic error during the flight that causes the screens to blackout, this can leave pilots in a very dangerous position because they have limited information to fly with. The user interfaces (UIs) can be difficult to operate because the pilot may accidentally touch the wrong button or knob on glass cockpits. UIs are a program that controls a display for the user, usually on a computer monitor, that allows the user to interact with the system. “The promise of greater levels of safety for glass cockpit airplanes have not been realized because general aviation pilots and training providers have not yet evolved in TAA training the way they train and fly to catch up with the advances in glass cockpit technology” (Littlefield, 2011).

Mode confusion will become a greater challenge as more and more system develops greater levels of complexity, automation and intelligence. Mode confusion can also occur when complex, automated systems interact in unexpected ways. Glass cockpit displays can present more information in the space required for conventional instrument panels (see picture below), but the increase in information places greater demands on pilot attention and creates a risk of overloading pilots with more information than they can effectively monitor and process.

Figure 1: Air Speed Indicator Mode

Source: http://blog.jetairgroup.com/tag/glass-panel/

Figure 2: Attitude Mode

Source: http://blog.jetairgroup.com/tag/glass-panel/

The complexity of the integrated computerized systems that drive glass cockpit displays may also limit pilots' understanding of the functionality of the underlying systems (National Transportation Safety Board, 2010). "The glass cockpit produces a problem of mode awareness. The pilot has to ensure they are continuously aware of when flying in a glass cockpit. Due to the fact that the flight and engine management systems can be set in various 'modes' (see List below), this offers the pilot the perception that the aircraft is carrying out one task when it is actually carrying out another" (Aviation Knowledge, 2011). This idea could be linked to the idea of setting a car on cruise control while driving down the highway.

"Pilots experience automation problems or "mode awareness" due to the fact that the primary flight-display can be set in various modes. This offers the pilot the perception that the aircraft is carrying out one task when in fact it may be carrying out another. Pilots may become confused by the computer generated messages from the different modes" (Aviation Knowledge, 2011). Several of the automated displays are similar to each other in appearance, as well as how data is shown on the screen. The Air Speed Automation Mode may be in use by the pilot one minute and then something could happen with terrain or weather and then the pilot has to switch to another mode and immediately interpret what is happening in the new mode display that was just switched to, all being done correctly and safely. This sometimes causes automation mode problems which ads additional stress to the pilot and crew of the flight.

Table 1: Possible Modes in a Glass Cockpit Aircraft

- Air Speed
- Attitude
- Flight Planning
- Landscape
- VOR (VHF Omni-directional Range)
- Time Lapse
- Terrain
- Weather
- Wind Speed/Direction

The breakdown in human machine coordination has been a problem in aviation, particularly in modern automated aircraft with glass cockpits. Glass cockpits contain considerable automation, the functions of which are governed by automation modes. A mode can be described as “a condition in the machine that corresponds to a unique behavior or a manner of behaving as well as to a device state that controls or displays functions in a distinct way or has a distinct meaning. Confusion about in which mode the automation operates can lead to automation surprises, where crew members think they have told the automation to do one thing, whereas it is actually doing another because it is in another mode” (Dekker, 2006, p. 258). “The fact that the auto flight systems in commercial aviation are not standardized across manufacturers is not making the interaction easier for the pilots. The features often seem to be the same, but different manufacturers have their own design philosophy for selection, activation, and annunciation of the different modes” (Dekker, 2006. P. 259).

Flying a glass cockpit aircraft requires a different cognitive style of thinking (Glass Cockpits, 2011). Some of those qualities include "paying attention to detail, visual and auditory processing and finally, logic and reasoning, all of which contribute to occupational success" (Cognitive Thinking, 2012). Converting from a traditional commercial aircraft with hundreds of individual instruments, to a glass cockpit aircraft with just a few displays requires more than just learning where to look. "Older pilots who have flown thousands of hours in traditional cockpits usually experience some difficulty transferring to glass cockpit aircraft" (Glass Cockpits, 2011). The age range of those older pilots was between 43 and 77. Pilots within that age range simply have more flight time in a conventional aircraft from earlier years of flight verses a glass cockpit equipped aircraft that they may just learning to fly. These pilots struggle with the aircraft doing the automation for them and the decrease of the workload that the pilot is usually responsible to perform in a conventional aircraft. The previous workload is then replaced with a new kind of workload, which can sometimes create information overload.

Training is clearly one key component to reducing the accident rate of airplanes equipped with glass cockpits. The studies completed all demonstrate the importance of training with TAA aircraft and glass cockpit systems. The data tells us that equipment specific training will save lives. Recommendations have been given in response to the data which included information on pilot knowledge testing standards, training, simulators, documentation and service difficulty reporting so that the potential safety improvements that these systems provide can be realized by the general aviation pilot community. Increased training means more time and more money will need to be put forth by those learning to fly and teaching to fly, as well as by those building and bettering aviation technologies, all in order to continue to make flight a possibility.

While many pilots have thousands of hours of experience with conventional flight instruments, that alone may not be enough to prepare them to safely operate aircraft equipped with glass cockpits. Safety and efficiency of flight have been increased with improved pilot understanding of the airplane's situation relative to its environment with the glass cockpit. When trying to answer the research question, how has aviation regulations changed in response to the implementation of glass cockpit technology in general aviation, all of the recommendations made to the FAA by the NTSB should be considered. Policies and regulations have become more specific and stricter for the well-being and the safety of pilots and passengers. The studies show that training is an important factor to this topic. Continuous active roles by the AOPA, NTSB and the FAA will always be taken in order to keep our skies safe.

CHAPTER 6

NTSB RECOMMENDATIONS

Recommendations were made to the FAA following recent accident investigation reports. The NTSB reports that, "advanced avionics and electronic displays can increase the safety potential of general aviation aircraft operations but alone are not helping to prevent accidents in the general aviation fleet. More effort is needed to ensure that pilots are prepared to realize that potential" (Grady, 2010). This can be achieved by providing pilots with more operational and safety related information and functionality. The NTSB said that the FAA can help to improve the impact of the technology and also improve the safety of general aviation operations beyond those involving aircraft with glass cockpit displays (National Transportation Safety Board, 2010).

The National Transportation and Safety Board released six specific recommendations in March of 2010 that were given to the FAA. These recommendations were based on a study entitled “Introduction of Glass Cockpit Avionics into Light Aircraft” which looked at the entry into glass cockpit equipped aircraft. The FAA should consider the recommendations and respond to the NTSB by making the necessary changes in order to improve the safety of today’s aviation industry. Five of these recommendations were training related. Accepting these recommendations and taking the appropriate actions are particularly important in order to achieve the potential safety benefits associated with advanced cockpit technologies in light aircraft.

The first recommendation was the need to “enhance pilot knowledge and training requirements” (National Transportation Safety Board, 2010). The FAA should revise airman knowledge tests to include questions regarding electronic flight and navigation displays, including normal operations, limitations, and the interpretation of malfunctions and aircraft attitudes.

The second recommendation was to "require manufacturers to provide pilots with information to better manage system failures" (Tresscot, 2010). The NTSB has determined that because glass cockpits "are both complex and change from aircraft to aircraft in design, function, and failure modes, pilots are not always provided with all of the information they need, both by aircraft manufacturers and the FAA to adequately understand the operational and functional details of the primary flight instruments in their airplanes" (National Transportation Safety Board, 2010). "The NTSB concluded that pilots are not always provided all of the information necessary to adequately understand the unique operational and functional details of the PFDs in their airplanes. The NTSB recommends that the FAA require all manufacturers of certified electronic PFDs to include information in their approved aircraft flight manual and pilot's operating handbook supplements regarding abnormal equipment operation" (Hersman, 2010, p. 4).

The third recommendation was to "incorporate training elements regarding electronic primary-flight displays into training materials and aeronautical knowledge requirements for all" (Tresscot, 2010). The NTSB recommends that the FAA include questions about glass cockpits on FAA Knowledge exams. Pilots need to receive equipment specific training on the technology installed in the aircraft they use, including the use of simulators. Pilots need to know how to report malfunctions. It was also recommended that manufacturers provide more information about what a pilot will see when glass cockpit avionics equipment fails (Experimental Aircraft

Association, 2010). “The NTSB concluded that simulators or procedural trainers are the most practical alternative means of training pilots to identify and respond to glass cockpit avionics failures and malfunctions that cannot be easily or safely replicated in light aircraft” (Hersman, 2010, p. 5).

The fourth recommendation was to “incorporate training elements regarding electronic primary flight displays into initial and recurrent flight proficiency requirements for pilots of small light general aviation airplanes equipped with those systems that address variations in equipment design and operations of such displays” (Tresscot, 2010). As aircraft equipment becomes more complex, the demands placed on pilots to manage and monitor equipment operation will continue to increase. Different systems require different operating techniques, and responses to failure and knowledge of one type of glass cockpit display are not likely to transfer to other systems. “The NTSB concluded that generalized guidance and training are no longer sufficient to prepare pilots to safely operate glass cockpit avionics, effective pilot instruction and evaluation must be tailored to specific equipment” (Hersman, 2010, p. 5).

The fifth recommendation was to “support equipment-specific pilot training programs by developing guidance for the use of glass cockpit simulators that are approved by the FAA as flight training devices” (Tresscot, 2010). The FAA should “develop and publish guidance for the use of equipment-specific electronic avionics display simulators and procedural trainers that do not meet the definition of flight simulation training devices prescribed in 14 Code of Federal Regulations Part 60 to support equipment-specific pilot training requirements” (General Aviation Manufacturers Association , 2010). The National Transportation Safety Board says it believes the data is "representative of a true effect", meaning that there had been no significant improvement in safety with the glass cockpits (Croft, 2010). The data that is looked at includes dates, times and location of accidents, pilot age and history, type of aircraft, causes of accidents, the number of people involved as well as and other factors the NTSB investigators feel are appropriate (National Transportation Safety Board, 2012). The NTSB released the results of a five-year study that concludes that glass cockpit avionics do not improve the safety record of light aircraft and that training, especially on specific equipment, is needed to maximize the safety potential of glass cockpit technology (Experimental Aircraft Association, 2010). These results support the recommendation that equipment specific pilot training needs to be incorporated glass cockpit flight training. Incorporating different training elements will have a huge impact on the improvement of glass cockpit safety issues for the future. Some training elements that could be incorporated include training on specific equipment. Because of this training, pilots will have a better understanding of the difference between electronic primary flight displays as well as the variations in equipment design and operations. Pilots will receive equipment-specific training by instructors. Instruction in glass cockpit simulators will allow pilots to receive practice and training as if they were actually in the air (National Transportation Safety Board, 2010).

The sixth and final recommendation was to “inform the general aviation community about the importance of reporting malfunctions or defects with electronic flight, navigation and control systems through the Service Difficulty Reporting (SDR) system” (Tresscot, 2010). By implementing this new policy of “informing aircraft and avionics maintenance technicians about the critical role of voluntary service difficulty reporting system reports involving malfunctions or defects associated with electronic primary flight, navigation, and control systems in certified aircraft used in general aviation operations., the aviation community will be allowed to better evaluate and investigate reports made through the SDR system to determine the cause of accidents and system failures in aircraft" (General Aviation Manufacturers Association, 2010). "The NTSB has made major recommendations for changes to the immediate incident reporting requirements regarding incidents, such as the need to report a failure of more than fifty percent of glass cockpit instruments" (Lamonaca, 2012). "With the new obligation that manufacturers are now faced with, pilots will be given the ability and confidence to better manage system failures and then successfully report them through the Service Difficulty Reporting site. The obligation that manufacturers have is to provide training on how to use the specific equipment and technology safety in the aircraft when needing to report malfunctions or difficulties" (General Aviation Manufacturers Association, 2010). The reporting system will allow changes and adjustments to be made to current systems in order to make improvements to increase safety.

CHAPTER 7

NEW AVIATION POLICIES

The FAA has introduced the FITS (FAA Industry Training Standards) program to emphasize the need for real-world training. The FITS program established a Private Certificate Instrument Rating syllabus in Technically Advanced Airplanes, but the FAA is still working on ways to successfully implement the training**.** FITS focuses on real world challenges. Scenario-based training is used to enhance the general aviation's pilots' aeronautical decision making, risk management, and single-pilot resource management skills (Federal Aviation Administration, 2009). This relates to TAA aircraft because the FAA's Knowledge Test questions were also reviewed and recommendations were made to add questions about integrated glass cockpit avionics such as Primary Flight Displays (PFD) (General Aviation Manufacturers Association, 2010). Single-pilot resource management (SRM) is "the art and science of managing all the resources available to a single pilot, both onboard the aircraft and from outside sources prior to and during flight, to ensure that the successful outcome of the flight is never in doubt" (Single-Pilot Resource Management, 2012).

By implementing FAA Industry Training Standards (FITS) and the Service Difficulty Reporting system (SDR), the FAA has addressed the recommendations made by the NTSB following their studies. FITS provides real-world training & challenges and is scenario based. It is in place to enhance aeronautical decision making, risk management, and single-pilot resource management skills. SDR enables the ability to electronically submit Service Difficulty and Malfunction & Defect reports and also allows the public to search and review all submitted reports on the FAA website (Federal Aviation Administration, 2009).

The FAA now requires that all manufacturers provide information in the Pilot's Operating Handbook about the safe operation of airplane systems and in the event of equipment malfunctions how to manage system failures and handle abnormal equipment operations (General Aviation Manufacturers Association, 2010). This new requirement addresses the second recommendation made by the NTSB. The FAA introduced the new Advanced Avionics Handbook in 2009 which specifically looks at glass cockpit avionics. The primary focus of the work to update the FAA's handbooks was related to improving cockpit resource management and presenting aeronautical decision making information more fully to pilots and instructors (General Aviation Manufacturers Association, 2010). This new handbook seeks to address the third recommendation made by the NTSB.

The NTSB now requires that all manufacturers of certified electronic primary flight displays to include information in their approved aircraft flight manual and pilot's operating handbook supplements regarding abnormal equipment operation or malfunction due to subsystem and input malfunctions, including but not limited to pivot and/or static system blockages, magnetic sensor malfunctions, and attitude-heading reference system alignment failures. "Airplane manufacturers and their partner training providers as well as the avionics manufacturers have established training programs for glass cockpits. Programs are now run in a number of locations including Cessna Pilot Training, Cirrus Aircraft factory training, and SIMCOM for Piper Aircraft". (General Aviation Manufacturers Association, 2010). "SIMCOM provides professional simulator based flight training for a wide range of piston engine, turboprop, and business jet aircraft, using the latest aircraft technology" (SIMCOM, 2013). The training has been well received by both customers and the insurance community. This new training from manufacturers addresses the fourth recommendation made by the NTSB. New aviation policies and regulations will have many positive impacts on aviation safety, on the ground and in the air. These positive impacts include improving the accuracy of flight, increasing the continuity of the aircraft navigation system and finally, enforcing the integrity of the navigation systems on the aircraft. All of these impacts ultimately improve safety. Studies will be conducted in the future in order to continuously improve aviation safety as new technology is developed. The impacts that new policies will have include empowering pilots with all the knowledge necessary in order to handle an emergency situation if they were to ever be confronted by on in the air. “Regulators are concerned that glass cockpits may be like a wonder drug whose negative side effects appear only later, flying schools, manufacturers and insurance companies share their anxiety” (MacDougall, 2007-2012).

CHAPTER 8

CONCLUSION

Not only has the implementation of glass cockpits brought many changes to the technological side of general aviation, but it has also brought many changes to the regulatory side of general aviation within the Federal Aviation Regulations (FARs). Airworthiness standards have changed in various general aviation aircraft with regards to weight limits and performance capabilities as well as pilot training, re-occurring training and instrument rating requirements. Airman testing and pilot training standards have grown to be increasingly stricter as a result of glass cockpits in the general aviation industry. FAA employees performing inspections on technical advanced aircraft have also been subject to increased training on technically advanced aircraft in order to meet practical testing standards (PTS). Within the FAA, "PTS is an examination which pilots must undergo in order to receive an aircraft pilot's certification, or an endorsement for additional flight privileges" (Federal Aviation Administration, 2009).

As a result of these changes in the Federal Aviation Regulations, the aircraft and pilot certification process, manufacturing of aircraft process as well as the cost of certification and manufacturing can also be expected to change. Changes such as these are being made only in an attempt to increase safety and make the aviation industry more efficient and reliable. Change does not happen overnight and will take time. As newer technologies develop in aviation new regulations must follow. It is important to recognize these changes as they occur and then work together in order to maintain the integrity of our aviation industry.

CHAPTER 9

RECOMMENDATIONS

Prior to reading the literature and studies completed on this research topic, I made a few suggestions of my own. My recommendations are not as specific as the NTSBs and the AOPAs recommendations, but my own recommendations were very similar with regards to what changes should be made in order to make air space safer for everyone. The one thing that can be done when using this new technology and make it safer is to prepare our pilots for every possible situation that they may encounter up in the air. This can only be accomplished through training.

In the beginning, flight training began in a conventional aircraft with a flight instructor, just as one would in a motor vehicle while taking driver's education. In the future, it is very possible that most general aviation aircraft, with a few exceptions, will be built with glass cockpits. When this occurs, it should be mandatory that all individuals receiving flight training begin their aviation career in a conventional aircraft. It is important that pilots know and understand how to fly an aircraft manually without the option of glass cockpit abilities in the event that the system malfunctions. When an aircraft is built with glass avionics technology, it should also be built with something to fall back on, such as a back-up system. As mentioned before, in the tragic event that systems fail in an aircraft while in flight, the aircraft should still be able to fly with the conventional back up technology. This is where the mandatory conventional aircraft training would come in to use for all pilots in the industry. Pilots need more training in the use of glass cockpit technology. Areas that pilots need to receive more training in are with electronic flight and navigation displays.

Glass cockpits are similar to conventional cockpits in the sense that they are both hands on when it comes to operating. With conventional airplanes, in the cockpit, everything that is needed to fly an aircraft is right in front of the pilot. With an airplane using glass cockpits, there is so much more in operation that the pilot does not see. The technology seems to do it all for them. With the touch of a pilot's finger, everything can change instantly, changing the direction of the aircraft, the altitude of the aircraft, even the airspeed of the aircraft. Accidentally bumping or touching the wrong part of the screen due to aircraft turbulence could bring about unwanted outcomes such as the increase of altitude, change in direction headings and increase in speed. This is why it would be important to increase glass cockpit training for new pilots as well as older pilots who only have conventional aircraft training. Additional training may not fully eliminate the safety hazards of flying an aircraft with glass cockpits but it could significantly reduce the fatality rate of accidents involving glass cockpit aircraft.

Accurately training pilots and providing them with the necessary knowledge needed to safely fly aircraft and address any potential difficulties while in the air is all that can be done prior to take-off. In any case it is better to be pro-active instead of re-active where safety is concerned.

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