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A Usability and Learnability Case Study of Glass Flight Deck Interfaces and Pilot Interactions through Scenario-based Training

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A Usability and Learnability Case Study of Glass Flight Deck Interfaces and Pilot Interactions through Scenario-based Training

by

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A dissertation submitted in partial fulfillment of the requirements
for the degree of a Doctor of Philosophy
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We hereby certify that this dissertation, submitted by Thomas De Cino, conforms to acceptable standards and is fully adequate in scope and quality to fulfill the dissertation requirements for the degree of Doctor of Philosophy.

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In the aviation industry, digitally produced and presented flight, navigation, and aircraft information is commonly referred to as *glass flight decks.* Glass flight decks are driven by computer-based subsystems and have long been a part of military and commercial aviation sectors. Over the past 15 years, the General Aviation (GA) sector of the aviation industry has become a recent beneficiary of the rapid advancement of computer-based glass flight deck (GFD) systems.

While providing the GA pilot considerable enhancements in the quality of information about the status and operations of the aircraft, training pilots on the use of glass flight decks is often delivered with traditional methods (e.g. textbooks, PowerPoint presentations, user manuals, and limited computer-based training modules). These training methods have been reported as less than desirable in learning to use the glass flight deck interface. Difficulties in achieving a complete understanding of functional and operational characteristics of the GFD systems, acquiring a full understanding of the interrelationships of the varied subsystems, and handling the wealth of flight information provided have been reported. Documented pilot concerns of poor user experience and satisfaction, and problems with the learning the complex and sophisticated interface of the GFD are additional issues with current pilot training approaches.

A case study was executed to explore ways to improve training using GFD systems at a Midwestern aviation university. The researcher investigated if variations in instructional systems design and training methods for learning glass flight deck technology would affect the perceptions and attitudes of pilots of the learnability (an attribute of usability) of the glass flight deck interface. Specifically, this study investigated the effectiveness of scenario-based training (SBT) methods to potentially improve pilot knowledge and understanding of a GFD system, and overall pilot user experience and satisfaction.

Participants overwhelmingly reported positive learning experiences from scenario-based GFD systems flight training, noting that learning and knowledge construction were improved over other training received in the past. In contrast, participants rated the usability and learnability of the GFD training systems low, reporting various problems with the systems' interface, and the learnability (first-time use) of the complex GFD system. However, issues with usability of the GFD training systems did not reduce or change participant attitudes towards learning and mastering GFD systems; to the contrary, all participants requested additional coursework opportunities to train on GFD systems with the scenario-based flight training format.

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Chapter 1

Introduction

Background

The development of military aircraft over the past 40 years has incorporated considerable computer-based improvements in weapons technology, targeting systems, and flight systems capabilities. Similarly, commercial passenger aircraft have incorporated significant computerization of the flight deck improving flight plan management, weather tracking and traffic reporting subsystems, and engine, fuel, and aircraft systems monitoring as evidenced by the likes of current manufacturers of jet aircraft Bombardier, Boeing, and Airbus commercial jets. Casner (2008, 2009), Mitchell, Vermeulen, and Naidoo (2009), and Mitchell, Kristovics, and Bishop (2010) discussed the considerable literature and documented studies on pilot perspectives and interactions with the usability of glass flight decks (GFDs) in commercial and military jet aircraft. However, only in the recent decade has the aviation industry's sector of General Aviation (GA) experienced similar considerable change in the computerization of instruments, flight navigation management, and radio communications through the use of computer-based subsystems.

General Aviation is defined as all flight operations except commercially scheduled passenger flight operations and military operations (Federal Aviation Administration [FAA], 2012; Mitchell et al., 2010; Shetty & Hansman, 2012). General Aviation represents all civil aviation operations including private use of aircraft, all business and non-scheduled charter flights, and all flight training operations. This most notably includes all pilot instruction and training that encompasses the educational foundation for all civilian, recreational, and career pilot education and training schools (Mitchell et al., 2010; Shetty & Hansman, 2012).

The advent of flight deck computerization for aircraft flown by GA pilots has placed a considerable training demand on those pilots (DeMik, Allen, & Welsh, 2008; Kearns, 2007, 2011; Mitchell, Vermeulen, & Naidoo, 2009). Pilots are having to transition from conventional analog instruments and gauges (often referred to as *steam gauges* or *round dials*) to the digitally generated and presented flight decks (often referred to as *glass cockpit* or *glass flight deck*) of today's modern GA aircraft (Casner, 2009; Kearns, 2007, 2011; Mitchell et al., 2009, 2010). The new training demands go beyond just learning a new computerized system; the training demands on pilots are now recognized as issues with usability and learnability of glass flight deck systems.

Kearns (2011) pointed out that a direct result of flight deck computerization is the considerable increase in the type and quantity of flight information available and displayed to the pilot, along with numerous options for automating many traditionally human-managed flight tasks. Digital presentation of glass flight deck information requires the pilot to learn new and different methods for interpreting and understanding abundant glass flight deck data, and which information presented is of the highest priority and need, at any given time during aircraft operations (DeMik et al., 2008; Kearns, 2011; Mitchell et al., 2009). In the context of learnability (an attribute of usability), pilots appear to be experiencing difficulties in the ease with which they are able to become proficient and productive with glass flight deck (GFD) systems because of systems complexity and the sophistication of information presented and available.

The introduction of highly computerized flight deck technology into GA training aircraft is as equally important an improvement for GA as it has been in commercial and military aircraft. Several studies report that most GA pilots welcome these improvements in flight deck technology (Casner, 2008, 2009; DeMik et al., 2008; Kearns, 2007; Kearns, 2011; Mitchell et al., 2010; Shetty & Hansman, 2012). For example, Casner (2009) and Kearns (2011) identified studies of pilot attitudes towards glass flight deck advanced weather and traffic monitoring subsystems as increasing pilot safety ultimately through the reduction in the number of weather-related accidents. Casner (2008, 2009), and Mitchell et al. (2009; 2010) outlined survey-based pilot studies noting that pilots generally perceive these digital flight deck improvements as positive steps towards aiding the pilot's management of their workload and their situational awareness. They cited pilots reporting beliefs that the use of global positioning system (GPS) devices and moving maps results in their flying with higher navigational awareness when operating flights with a glass flight deck.

Casner (2008, 2009) and Mitchell et al. (2009) also presented survey data showing pilots believe GFD subsystems such as the autopilot, automated navigation sequencing technology, and aircraft systems fault monitoring and alerting systems improves pilot decision-making skills, and overall flight safety. Casner (2008, 2009) summarized his GA studies of pilots' general attitudes toward GFD systems, noted the pilots surveyed "seemed to prefer to fly glass flight decks because they believed the advanced cockpit systems offer specific benefits such as lower workload" (2008; p. 110), "help enhance awareness", and "head off certain types of errors" (2009; p. 448). Mitchell et al. (2009) underscored their research study results that showed the continuation of a general consensus among pilots dating back to the mid 1990's that "glass cockpits were much safer to fly than non-glass cockpit aircraft" and "glass cockpits have made aircraft much safer and more reliable" (p.11).

Glass flight deck technology introduces many nuanced enhancements in avionics, and an array of additional aviation information to the pilot, all presented on multi-colored displays instead of conventional analog instrumentation (Baxter, Besnard, & Riley, 2007; Casner, 2009; Mitchel et al., 2009). Baxter, Besnard, and Riley (2007) and Hahn (2012) posited this increase in technological sophistication of the flight deck has also introduced a notable increase in a pilot's training requirements necessary to properly utilize these various systems enhancements while flying the aircraft. Several authors found this similar to automobile drivers, who when using a GPS navigation system in an automobile for the first time, recognize the ease of the act of driving the car can be drastically disrupted by the mere effort and focus on trying to work with the GPS to navigate to a destination (Casner, 2008; Jensen, Skov, & Thiruravichandran, 2010; Mitchell et al., 2010).

Much like a current-day personal computer, this doubling and tripling of information available makes for a complex and crowded set of information screens – further complicated by the cascading menu selections the pilot manipulates using peripherally-ringed buttons, switches, and dials that serve multiple functions depending on the subsystem in use. The increase in complexity and sophistication of flight deck technology in GA aircraft has produced a critical need for new training approaches to enable GA flight instructors to teach on these incredibly information dense, highly configurable GFD systems (Casner, 2009; FAA, 2007; Hahn, 2012; Kearns, 2011).

Hahn (2012) pointed out that legacy aviation training methods of 75 years ago predominately involved putting pilots in airplanes and telling them to learn to fly the airplane as they went. In today's digital flight deck complexity of GA aircraft, Hahn (2012) offered that contemporary flight instructors would not even consider using a *learn as you go* method for aviation training in today's flight environment. Flight instructors seem to recognize that their students' ability to master the glass flight deck system is difficult. They find helping their students' in learning the glass flight deck system to a proficient level requires considerable training. They understand the wealth of information and complexity of the technology make the learnability of the system daunting.

Research on the usability attributes of learnability and user satisfaction should serve to benefit pilots training on glass flight deck systems, and should inform those that are responsible for creating and delivering the training. Additionally, research on the usability attributes of learnability and user satisfaction will potentially benefit the manufacturers of these systems in future designs of GFD subsystems, and in the manner in which the technology presents and displays pilot information. Chilana, Wobbrock, and Ko (2010) noted existing usability research has traditionally addressed human-computer interactions at desktop and application levels, and in web-based environments. They proffered that new usability research techniques must be developed and applied reflecting the complex domain in which these sophisticated technology systems are designed and implemented. Aviation is one such complex domain, where flight training processes stand to reap significant benefits from research on learnability and usability of glass flight deck systems.

This research study is unique and new given the review of the literature reveals that currently there is limited research on the usability of GA glass flight deck systems. Similarly, there appears to be limited current research on the use of scenario-based pilot training methods applied to teaching the proper use of GA glass flight deck systems. While studies have been done to assess commercial airline pilot perceptions of GFD systems (Mitchell et al., 2009; Naidoo, 2008) and isolated studies on pilot perceptions of GA aircraft advanced cockpits (Casner, 2008; Mitchell et al., 2010), the literature review did not reveal studies specifically assessing the usability constructs of learnability and user satisfaction of GA glass flight deck systems. A few studies exist on the feasibility of scenario-based training for training and evaluating pilots on general aviation topics and principles (Craig, 2009, Kearns, 2011). Likewise a few studies were found using scenario-based training methods in teaching aviation safety and risk management skills (DeMik et al., 2008; Summers, 2007). However, the literature review did not reveal studies specifically assessing the use of scenario-based training for pilots teaching and learning the proper use of GA glass flight deck systems.

Problem Statement, Goals, and Research Questions

Complex technology systems that are difficult to master and use, often create problems of usability for system users; this in turn may negatively affect a system users' experience working with the system and often translates into an overall poor user satisfaction (DeMik et al., 2008; Kearns, 2011; Mitchell et al., 2009). The ease of learning a technically complex system – the system's learnability – is an essential usability attribute that must be considered. Learnability, then, must be observed and measured in the training of pilots on GFD systems. User experience and satisfaction with this complex technology is partly a function of the learnability of the system, and particular to glass flight deck systems, learnability directly affects both flight instructors and pilot students of these new technologically complex systems during the training process.

As digitally-based glass flight deck technology is increasingly encountered in GA training aircraft, flight instructors must be better prepared to teach in training aircraft with the sophisticated technology – and this is new technology that they must first learn to use prior to facilitating instruction (DeMik et al., 2008; Mitchell et al., 2009). It appears it is common for flight instructors to only be moderately experienced beyond the pilots they instruct, and in understanding the complex workings of the glass flight deck. This frequently translates into flight instructors training their pilot trainees on which buttons to push or knobs to turn to achieve a certain result, instead of teaching their pilots to do more than just manipulate the multiple interfaces of the glass flight deck (Kearns, 2011; DeMik et al., 2008; Mitchell et al., 2010). The FAA (2006) acknowledged that with older GA aircraft analog instrumentation, flight decks mostly looked and functioned similar, regardless of the aircraft model manufacturer, and as such training across different types of aircraft models was consistent. However, newer GFD systems that perform the same or similar functions may not look or act alike, and pilot training requirements with GFD subsystems are often necessarily different from one model of aircraft to another (Baxter et al., 2007; FAA, 2003).

Casner (2008) and Mitchell et al. (2010) pointed out that no formal training requirement on glass flight deck technology of flight instructors is currently required. When coupled with a lack of standardization of glass flight deck training curriculum, both Hahn (2012) and Kearns (2011) noted flight instructor experience and training varies from instructor to instructor, and has a direct impact on the quality of training pilots ultimately receive. Casner (2008) and Mitchell et al. (2010) found that flight instructors' training is often left to learning from their peers and mentors, reading manufacturer user manuals for the various subsystems, and referencing explanations of functionality from textbooks or third-party training manuals. They emphasized this tends to produce only declarative knowledge, but often not the additional procedural knowledge required of any pilot necessary to master GFD systems.

It is not enough to know just which button or dial to push or turn. Kearns (2011) suggested a more appropriate way to master learning the full capabilities of the glass flight deck would seemingly involve improving the training methodology on the effective use all GFD subsystems and resources in pursuit of efficient and safe flight operations. Hahn (2012) offered that training should focus on how to utilize the various information presentation and monitoring resources in a way that aids in understanding the interrelationships of the multiple subsystems that underlie glass flight deck technology. Training should also focus on improving the learnability of the various glass flight deck subsystems, ultimately influencing the pilot's usability experience, and the overall usability of the entire GFD system. Several researchers also emphasized that learning how to maximize application of those subsystems' relationships as being critical (DeMik et al., 2008; Kearns, 2011; Mitchell et al., 2009). This is essentially consistent with the pursuit of the primary priority for all pilots – flying the airplane in a safe and controlled manner, within the present airspace conditions, according to the federal rules and regulations for the type of flight being conducted (Craig, 2009; Hahn, 2012; Kearns, 2011; Summers, Ayers, Connolly, & Robertson, 2007).

The Problem Addressed

The problem addressed in this research study was the lack of effective training and learning methods for flight instructors and pilots in mastering the GA glass flight deck system. Effective training and learning methods require improvement so that there is proper mastery of the various complex subsystems that underpin the GFD system (functional use of the various knobs, switches, and dials serving each subsystem). Additionally, training and learning methods should be improved to teach the proper use, integration, and application of each of those subsystems as a part of the greater GFD system (Craig, 2009; DeMik et al., 2008; Hahn, 2012; Kearns, 2011; Mitchell et al., 2009).

Craig (2009) and Kearns (2011) advocated a possible approach to improve training and learning may be found using scenario-based training methods managed by mentoring flight instructors. Through the use of flight scenarios that are representative of the common flight experiences pilots have in flying aircraft, it has been shown to be effective and productive in achieving positive training results and performance improvements (Craig, 2009; DeMik et al., 2008; Hahn, 2012; Kearns, 2011, Mitchell et al., 2010). The overarching focus of the study was that use of flight scenarios may further clarify if the learnability of GFD systems can be improved by the use of scenario-based flight training sessions, and what affect, if any, there is on the pilot’s user experience and satisfaction. The study also helped to clarify if the problems of usability as reported by pilots during training sessions, were usability problems related to the equipment designs and layouts, to the training methodologies employed to master GFD systems, or a combination of both.

The goals of the study were to investigate:

1. If the user learning and training process for GA pilots on GA aircraft glass flight deck systems is improved through implementation of scenario-based training approaches (Craig, 2009; Hahn, 2010; Summers, et al., 2007).
2. If the quality of the pilots' learnability and usability experience through scenario-based training approaches to GA aircraft glass flight deck systems improves their satisfaction with, and perceptions and attitudes regarding their training experiences on, GA glass flight deck systems (Casner, 2008; Craig, 2009; Mitchell et al., 2010).
3. If improvements in the quality of the training experience of pilots, if accomplished through scenario-based training approaches, improves the pilot perceptions and attitudes regarding their overall use of and reliance on GA aircraft glass flight deck systems (Casner 2008; Craig, 2009; Mitchell et al. 2010).

Through the investigation of these goals, the following research questions were addressed:

1. To what extent does the quality of user learning and training experiences improve by utilizing a scenario-based training approach to the use of glass flight deck systems by pilots?
2. To what extent does the quality of the learnability and usability experience of pilots utilizing a scenario-based training approach improve their satisfaction with, and perceptions and attitudes of their use of and reliance on glass flight deck systems?

3. What, if any, are additional instructional designs improvements in glass flight deck training suggested or found through implementing the changes in the training methodology as proposed?

This study is a hybrid exploratory and descriptive single case study of flight instructors and pilots on the usability of GA glass flight deck at a Midwestern aviation university. Exploratory case studies of technology-driven training environments seek to understand new situations or problems - such as those documented with pilot training and user experience issues of learning GFD systems – and often includes direct observation and interviews of the events or persons studied (Lazar, et al., 2010; Yin, 2014). The study sought to explore and better understand pilot training and user experiences (e.g. suability and learnability) of GA glass flight deck systems under traditional versus scenario-based teaching and learning strategies.

Descriptive case studies often document the context of technology use such as described in this study, and lessons learned that might be of future research interest (Lazar, et al., 2010; Yin, 2014). The researcher sought to describe what changes, if any, occur with pilot perceptions of the usability of GFD systems through the incorporation and use of scenario-based instructional methods, and if pilot perceptions of their training experience are changed because of the inclusion of scenario-based training.

The researcher engaged a group of pilots made up of flight instructors, commercial pilots, and pilot trainees. The group of pilots followed specific training approaches to learn the GFD system. The training approaches included traditional training using legacy resources (textbook, lecture, presentations, etc.), traditional training of a self-paced, independently-driven learning approach using typical manufacturer-supplied manuals and training software, a hybrid training technique using scenario-based learning concepts coupled with hands on simulation, and the application of flight scenarios in actual aircraft simulation devices.

Relevance and Significance

The corpus of literature reviewed points to continued positive perceptions and attitudes of pilots regarding the improved flight environment and safety experience achieved through technological advancements in the glass flight deck (Casner, 2008, 2009; DeMik et al., 2008; Kearns, 2007, 2011; Mitchell et al., 2009, 2010; Shetty & Hansman, 2012). Flight instructors and pilots perceived the increase in the amount and type of flight information via glass flight deck technology as being a positive and welcomed benefit to the flight deck. Many of the studies reviewed indicate flight instructors and pilots agree with the FAA’s perspectives that glass flight deck technology improves safety during flight, the pilot’s situational awareness, and overall workload management (Casner, 2008, 2009; Kearns, 2011; Mitchell et al., 2009, 2010; Shetty & Hansman, 2012). The considerable survey data also indicated flight instructors and pilots continue to perceive glass flight deck technology as important in aiding and improving critical decision-making skills and the overall safety of all flight operations.

In contrast, there are equally corresponding perspectives of concern from flight instructors and pilots that the glass flight deck presents issues with aspects of usability, primary training approaches, and ongoing currency training concerns. Pilots have welcomed the new glass flight deck technology in GA aircraft, but have maintained some concerns about inadequacy of comprehensive training and learning on the inter-relationships of glass flight deck technology subsystems as potentially leaving many pilots with only a limited understanding of basic glass flight deck operations and a diminished training experience (Baxter et al., 2007;

Casner, 2008; Kearns, 2011; Mitchell et al., 2009, 2010). Pilots reported concerns of the potential loss or degradation of flight skills, loss of situational awareness, increased workload as sophistication of glass flight deck technology increases, and a dependency, reliance, or complacency on the GFD systems to manage and fly the aircraft (Casner, 2008; Mitchell et al., 2009). Pilots have voiced opinions on lack of standards and consistency for training on GA aircraft with glass flight deck technology, reflecting on having to resort to use of limited quality training content found in textbooks, manufacturer manuals, and limited static computer-based training (CBT) programs (Casner, 2008; Mitchell et al., 2010).

Pilots reported concerns with using components and subsystems of glass flight deck interfaces noting that problems often were only discovered during actual day-to-day operations (Casner, 2009; Mitchell et al., 2009). Comprehensive learning of the systems was also frequently expressed as a concern as the sophistication of glass flight deck technology introduces considerably more complex flight information, and pilots reported their training experiences as being less satisfactory than desired (Mitchell et al., 2010). Of concern regarding the wealth of new and additional information presented digitally inside the flight deck, pilots expressed concerns about mental and task overload due to crowed sets of information. They pointed to buttons, switches, and dials that produce complicated menus and menu-subsystems resulting in an increase in complexity and the difficulty of operating sophisticated glass flight deck technology, often decreasing the quality of the pilot's use, experience, and satisfaction. This theme was encountered repeatedly in discussions on the training and experience of new and limited-time pilots (Baxter et al., 2007; Casner, 2008; Mitchell et al., 2009, 2010). Carroll and Rosson (2003) described these kinds of issues as concerns with respect to the usability of a computer system - its ease of learning, ease of use, and the user's satisfaction. These usability concerns, known as attributes of usability (e.g. learnability, ease of use, and user satisfaction) are at the core of this study.

These types of issues are also considered usability concerns as defined in Nielsen's systems acceptability framework. Nielsen's framework for systems acceptability, defines usability is a series of constructs of usefulness in a user interface. The pilot training issues and concerns identified can be grouped or categorized as two of the five of Nielsen's usability constructs – that of learnability and user satisfaction (Nielsen, 1993). As focus on user experience (UX) has grown in usability research circles over the past decade, Bargas-Avila and Hornbaek (2012) emphasized the importance of continued evolution of usability research into the quality of a user's (subjective) experience and satisfaction as such might encountered with complex interactive devices like a GFD system. They proffered that usability researchers need to further emphasize looking at user behavior to strengthen usability research through work on user-centered (scenario-based) models. Similarly, these two usability constructs can also be categorized according to Hertzum and Clemmensen's (2012) model wherein usability is a balancing act between utilitarian and experiential aspects. Nielsen's usability construct of learnability would be placed within their utilitarian group, and Nielsen's user satisfaction (and experience) as being part of their experiential group.

The results from this study may inform related training approaches in several different but complex domains. The fields of computer-based training, aviation training, and human-computer interaction (HCI), and other high-risk, high-stress, highly trained fields are examples of such complex domains. Research on new training approaches, such as executed in this study, may benefit the field of pilot training in aviation as more sophisticated glass flight deck technology continues to be introduced into GA training aircraft over the next decade. Foreseen by the FAA (2003, 2006), current training methods are not up to date with glass flight deck technology advancements, and research results from this study could directly inform and impact FAA-approved training curriculum.

Noting that usability research needs to evolve to be effective in dealing with and addressing complex domain environments, Villaren, Coppen, and Leal (2012) argued for more user-centered models of usability construct testing as applied to the complex domain of aviation training on highly technical and advanced avionics systems. Carroll and Rosson (2003) proffered that as new technologies bring about new opportunities for people to accomplish tasks in new ways, new training needs must evolve to aid them in reshaping their tasks and activities. They argued that user-centered scenario-based design and evaluations serve a fundamental role in unifying the overall user training and experience, while maintaining individualized user behavior and interactions unique to each user experience. Summers, et al., (2007) offered numerous reasons why scenario-based learning offers improvements in both pilot learning and experiences, underscoring pilots are better prepared for the entire training process. Craig (2009) pointed to greater training benefits realized by pilots through the use of scenario-based training, noting a direct "increase in pilot's critical thinking skills and makes them more comfortable and assertive in decision-making circumstances" (p. 169), and "pilots' overall increased enjoyment" (p. 168) with the training process.

Through deeper exploration of the usability constructs of learnability and user satisfaction of GFD systems, improvements in pilot training, use, and experience should be realized. Kearns (2011) suggested the quality of GA glass flight deck technology training curriculum stands to see improvements as more effective instructional methods are identified and developed, and should ultimately allow for standardization of both aviation content and delivery. Improvements in computer-based training should provide for non-technical aviation training to be delivered in an identical fashion regardless of the pilot's geographical training location. Delivery of new manuals, textbooks, and curriculum content will also be a benefit. Adaptability of training approaches should occur as training is molded and delivered to the specific needs of the pilot in training, and based on the type and extent of glass flight deck technology available in the training aircraft. Taken together, improvements in glass flight deck usability and pilot (user) training for the field of aviation are very likely transferable to other high-risk, high-stress, highly trained fields such as medicine, nuclear energy, air traffic control, high-speed commercial transit, and military operations.

Barriers and Issues

There are various issues and barriers associated with this study on glass flight deck technology in GA aircraft. For example, there are different topical areas associated with future designs of GFD systems, for which additional (future) research will likely have to occur. These include areas of manufacturer design and development of GFD subsystems (e.g. the use, type, amount, and overlay of graphic images) and use of heads-up display devices (fonts, typefaces, and screen layouts, icons, animations, aural alerts, etc.) and related information presentation and retrieval concepts. Issues such as handling extreme and complex domain environmental variables, screens or displays orientation, use of touch and gesture technology advancements, and inclusion of speech recognition in flight deck communications processes all require additional research. These design issues and challenges exist beyond the scope of this study.

The nature of just how new the glass flight deck technology to GA is well documented in the literature, and underscores that technological advancements in GA aircraft are still relatively young. Often cited is the somewhat quick appearance and application for GA aircraft in the past 10-15 years, compared to the somewhat slower methodical adoption rate of the military and commercial airlines of four to five decades (Casner, 2008; Kearns, 2011; Mitchell et al., 2009, 2010). The novel provision of glass flight deck technology by manufacturers of GA aircraft also presents some barriers. While traditional research on design usability was done by dominant commercial avionics manufacturers, the literature seems to suggest much of it comes from manufacturers' experience in developing advanced avionics specifically for the commercial airlines and military markets, and attempts to transfer that experience to GA markets.

Flight instructors and pilots have expressed concerns regarding the variations of glass flight deck technology implementation by avionics manufacturers. A unique aspect of the computerization and automation of GA flight decks has been the variety of devices and components from different manufacturers producing sub-parts that are considered part of the overall GFD system (Casner, 2008, 2009; Kearns, 2007; Mitchell et al., 2010). Given the considerable research, development, and manufacturing costs to create an entire GA-specific glass flight deck system, there are only a few select manufacturers making complete turnkey systems. This variety of different glass flight deck technology deployed in GA aircraft has been identified to be a concern for pilots training and learning across disparate subsystems or entire GA glass flight deck systems as manufacturers' design and implementation efforts vary from system to system (FAA, 2004, 2006).

However, the positive perceptions of pilots in employing this new glass flight deck technology are also well established (Casner, 2008, 2009; Kearns, 2007, 2011; Mitchel et al., 2009, 2010). Pilots have expressed positive acceptance of the new technology, while at the same time reflecting somewhat cautiously on the rapid deployment of the glass flight deck. Coupled with the short history of glass flight decks in GA, and a rather rapid adoption rate, pilots have expressed concerns over the transition from an analog to digital flight deck. These concerns are substantiated when pilots express concerns about a lack of standardized training programs. Also identified are training issues of proper learning and usability, and ultimately concerns of reliance or dependence on technology to do what traditionally has been the pilot's responsibility.

Issues and limitations should be addressed that include potential bias from the researcher's perspectives and assumptions, newness of the research as designed, the scope and time of this study, and the profile of the study's location, the training equipment, and the participants. The researcher's perspectives and assumptions must be recognized as possible issues for the study (Creswell, 2013, 2014; Schram, 2006). Potential researcher bias exists as a natural aspect of both personal and professional perspectives and experiences that may have affected this study. Perspectives and experiences of training with glass flight deck technology exist as the researcher holds a pilot license and has received pilot training over a period of years that include instruction on the use of glass flight deck technology in GA aircraft. The researcher brings personal, pilot–oriented assumptions and perspectives based on past training and instructional experiences with GFD systems.

From the researcher's professional position as manager of a professional multi-million dollar training facility at the Midwestern aviation university, the researcher has been tasked with improving the simulation and training environment for the department's aviation students. In particular, the past five years have been spent specifically on upgrading and implementing new flight training devices and CBT systems for the training on GFD systems. The efforts in this professional setting over this timeframe have also produced flight instructor-oriented assumptions and perspectives that the researcher brought to this study.

The researcher brought these perspectives and assumptions based on his own past training and experience, but every effort has been made to remain aware of potential biases through critical self-reflection, through processes of "reflexivity" and "bracketing" (Creswell, 2012; Rossman & Marshall, 2011; Schwandt, 2007). Every effort has been made by the researcher to remain objective, and to stay uninfluenced by personal and professional experience regarding the relationship with the participants, the data collection efforts, and the results analysis. A constant effort to "bracket" or set aside personal and professional perspectives was made throughout the study (Creswell, 2012; Munhall & Chenail, 2008; Schwandt, 2007).

Given this study is new and unique, the scope and timeframe for the study were necessarily restricted. Completed at a Midwestern aviation university, the scope of the study encompassed only the flight training facilities, simulation and flight training devices, and participants of the higher education institution. No plans were made to incorporate pilots from outside the university's aviation department. Additionally, the time frame for the study was projected to last less than one year. Following the traditional higher education school year wherein two semesters (fall and winter/spring) constitute a typical university student's higher education attendance, the study had to follow traditional coursework timelines to insure the group of pilot participants remained consistent and stable in pursuit of trustworthy and reliable study results.

The timeframe and scope of the study were closely scheduled and followed to insure the study was completed according to the methodological approach. Given the limits to the location, equipment, and participants involved, the researcher points out that the results are not intended nor expected to be generalizable to all pilots, but are only applicable to those pilots within the Midwestern aviation department's student pilot population. It was the researcher's expectation that through the exploration and description of the pilot learning and training processes, the results would inform and advise the aviation department's curriculum and training methods on areas for improvement in GFD systems training. It is the researcher's perspective that the research study was successful in establishing an initial effort for developing perspectives for ongoing future research, including pursuit of longitudinal studies, at the Midwestern aviation university's location.

Assumptions, Limitations, and Delimitations

Assumptions

The researcher held a number of assumptions regarding the study, the stated problems, and the goals and objectives. The researcher's previous personal experience and professional observations with formalized pilot training of GFD systems led to interest in investigating the training and learning methods currently used. Accordingly, the review of literature suggests there are usability and learnability issues as identified from surveys on pilot perceptions and attitudes with glass flight deck training. From these experiences and the literature reviews, this researcher presupposed there is lack of effective training and learning methods for pilots on GFD systems.

Another assumption held by the researcher was that a pilot's construction of knowledge about GFD systems is highly variable and locally specific to the pilot, their training environment, and the training regimen encountered. Based on the researcher's understanding of constructivist-based approaches to learning, it appears that constructive learning is fundamental in this type of training as a pilot's acquisition of glass flight deck knowledge is an active learning process, and seems to be founded in their own individual training experiences as they procedurally learn, relearn, and apply what is being taught in pursuit of mastery of GFD systems. It was assumed that to find more effective learning and training strategies, one must understand what pilots do and why they do it in the context of the training experiences they have.

Furthermore, it was the researcher's assumption and perspective that pilots best construct knowledge on proper use of GFD systems through understanding the connections made between the glass flight deck subsystems and their interrelationships to the whole glass flight deck environment. It was also assumed that there are common learnability and usability issues experienced by pilots in general when training on GFD systems. These assumptions led the researcher to the position that scenario-based training may be an effective alternative strategy to improve training experiences and results with GFD systems for pilots and flight instructors.

Limitations

Most qualitative study limitations evolve from the study and are easier to identify once the study is completed. However, a few limitations were identified prior to execution of the study albeit the researcher had no control over these limitations. The first limitation involved the likelihood that the study findings would only pertain to a certain set of pilots. The study was necessarily a partial description of the specific problems associated with the described glass flight deck learning and training regimens for pilots.

The second limitation was the findings were not expected to be construed as possible generalizations to a larger pilot population. The researcher acknowledged it was possible that the study findings would only be transferable to similar pilots training on glass flight deck systems in similar training environments on similar glass flight deck systems. The third limitation was this study was purposely limited and not intended be an exhaustive study of all pilot training. Certainly, these limitations would be even further restrictive in that applying the findings may only be to the pilot participants selected for this specific case study.

Delimitations

The researcher delimited the study in a number of ways. Delimitations included the duration of the training regimen, the training location, the training participants, and the training environment. The researcher delimited this study to the case as bounded by the Midwestern aviation university pilots and flight instructors, and purposely set the duration to roughly one week and one specific subject area of glass flight deck system training. Additionally, the study was further delimited by the two select sub-groups of pilots chosen and defined by their status as instrument pilots or certified flight instructors. This aided in a concentration of focus on the training directed at these groups. The study was also delimited by the training environment and the training equipment chosen, in keeping all training on the same GFD system, and in utilizing the same flight simulation devices. These delimitations placed upon the study design were ultimately in place in order to aid the researcher in keeping the study manageable and controlled.

Definitions of Terms

Computer-based training systems:

Subject matter training that is completed by students, usually in self-paced modules, on a computer system. Student completion progress and performance can be monitored and scored providing immediate feedback. Computer-based training (aka computer based instruction or CBI) often includes using devices in addition to, or as an alternative to, the mouse and keyboard (e.g. joystick, pointer, digital pads or tablets, etc.) used to complete the training (Schunk, 2012; http://en.wikipedia.org/wiki/E-learning).

Federal Aviation Administration:

The FAA is the national aviation authority of the United States. An agency of the United States Department of Transportation, it has authority to regulate and oversee all aspects of American civil aviation. Tasked with oversight of all civil aviation aspects, the FAA inspects and rates civilian aircraft and pilots, enforces the rules of air safety, and installs and maintains air-navigation and traffic-control facilities. The FAA was founded on August 23, 1958 (http://www.faa.gov/about/history/brief_history).

FITS – Federal Aviation Administration Industry Training Standards:

FITS is a program establishing partnerships between the FAA, the aviation industry, and academia. Designed to enhance General Aviation safety, the program established standards for these partnerships to develop flight-training programs that can be used to enhance the GA pilots' aeronautical decision-making, risk management, and single pilot resource management skills (FAA, 2003).

Flight training devices:

A device that closely duplicates a given aircraft make and model, it artificially re-creates aircraft flight, and frequently includes visual displays of the outside environment or world in which it flies. Used for pilot training, these training devices provide a safe and effective practice and training environment (FAA, 2008).

General Aviation:

General Aviation is a sub market of the overall aviation industry. General Aviation is defined as all flight operations except commercially scheduled passenger flight operations and military operations. General Aviation represents all civil aviation operations including private use of aircraft, all business and non-scheduled charter flights, and all flight-training operations. This specifically includes all pilot instruction and training or education for all civilian, recreational, and career pilots (Shetty & Hansman, 2012).

Glass flight deck subsystems:

Flight deck instruments and gauges that are created digitally as computer–generated graphics and presented via various forms of displays are examples of glass flight components. Glass flight deck components and operations that are integrated into small groups of related functions (e.g. communications, navigation, engine monitoring, aircraft performance, etc.) are referred to as glass flight deck subsystems (Mitchell et al., 2010).

Glass flight deck systems:

Entire flight deck subsystems (e.g. avionics, engine monitoring, aircraft performance, etc.) integrated into larger systems, and digitally generated by computer systems as a whole flight deck system, are referred to as glass flight deck systems (Casner, 2008; Mitchell et al., 2010).

Global Positioning System:

The Global Positioning System is the space-based satellite navigation system providing time and location information. This information is available in all weather conditions anywhere on or near the earth as long as the GPS receiving device has an unobstructed line of sight to a minimum number of GPS satellites in medium earth orbit (http://www.faa.gov/about/office_org/headquarters_offices/ato/service_units/techops/navservices/gnss/gps/).

Human-computer interaction:

Human–computer interaction involves studying the planning, design, and how humans use computers. This field of study looks at how humans use and interact with computers, and how and why computer systems might be made easy, simple, and productive for human use. As a study of interaction between people and computers, it is can be regarded as the intersection of computer science, behavioral sciences, design, and other fields of study (Carroll, 2000; Hassenzahl, 2013; Lazar, Feng, & Hochheiser, 2010; Rosson & Carroll, 2002).

Instrument flight rules:

Defined as flights which are conducted by reference to the aircraft instruments when visibility is reduced, often with little to no reference to earth's landforms or horizon. Also known as instrument flight conditions that often require the pilot to fly and navigate through the clouds. (Willits, 2014).

Learnability:

This is a measure of the degree of ease in learning a system such that the user can become proficient and productive with basic and necessary tasks in using the system. It can also relate to a user's ability to relearn a system after an extent of inactivity. Learnability is recognized as one of several attributes of usability (Nielsen, 1993; Rubin & Chisnell, 2008).

Round dials or steam gauges:

These are the traditional instruments and gauges with which aircraft flight decks have long been configured. They were often analog based devices with needles and mechanical moving parts similar to many clocks and timepieces of old. These devices had little or no LED or LCD displays presenting the information to the pilot (http://www.faasafety.gov/gslac/ALC/libview_normal.aspx?id=15239; http://flighttraining.aopa.org/magazine/2011/May/the_transition.html).

Scenario-based training:

In flight training environments, a scenario-based training approach would include multiple flight training scenarios and exercises to provide pilots real-world situational learning events to master the knowledge and skills needed for real-world situations that would otherwise be too high-risk, high-stress, or violate safety protocols to be attempted in real-world settings. Focusing training on mastering and managing real world situations, scenario-based training is one example of FITS program training approaches. It has been found to be useful in enhancing GA pilots' aeronautical decision-making, risk management, and single pilot resource management skills (Carroll, 2000; Hahn, 2010).

Usability:

Usability can be considered the quality of a system with regard to the ease of learning it, the ease of using it, and the extent of the user's satisfaction. Usability is often defined as having multiple attributes (e.g. learnability, memorability, errors, user satisfaction, etc.) (Hassenzahl, 2013; Nielsen, 1993; Rosson & Carrroll, 2002).

User experience:

A term used to describe a human's subjective experience and satisfaction (behaviors, attitudes, and emotions) about using a particular product, system or services. It can also be described as the experience that a user has, emerging from the integration of emotion, perception, action, motivation, and cognition of using a product, system or service, that make up the user's perception of the whole. A field of study within HCI, user experience includes the person's perceptions of system aspects such as utility, ease of use and efficiency (Hassenzahl, 2013; Rosson & Carroll, 2002; Rubin & Chisnell, 2008).

User satisfaction:

User satisfaction is a subjective measure, and relates to the attitude of a user towards a system, and how pleasant a system is to use. User satisfaction is one of the several attributes of usability (Nielsen, 1993; Rosson & Carroll, 2002; Rubin & Chisnell, 2008).

Very light jets:

Very light jets are a category of small GA jet aircraft typically equipped with high tech flight deck environments where GFDs are prevalent. VLJs are approved for single-pilot operation, typically seat four to eight people, and have a maximum take-off weight of less than 10,000 pounds. Designed to be flown by single pilot owners, they are lighter than business jets Kearns, 2011; DeMik et al., 2008).

Visual flight rules:

These are rules defining flights which are conducted by maintaining visual contact or reference to the earth's landforms or horizon. They also refer to the visual flight conditions that require the pilot to fly and navigate free and clear of clouds. (Willits, 2014).

List of Acronyms

The following is a short list of acronyms used in this dissertation.

CBT – computer-based training

CFI – certified flight instructor

FAA – Federal Aviation Administration

FITS – FAA's Industry Training Standards concept and programs

FTD – flight-training device

GA – general aviation

GFD – glass flight deck

GPS – global positioning system

HCI – human computer interaction

IFR – instrument flight rules

SBT – scenario-based training

TAA – technically advanced aircraft

UX – user experience

VLJ – very light jet

Summary

Over the past several decades, manufacturers of aircraft have increased the level of computer-based technology used in military, commercial passenger, and GA aircraft. The increase in use of computer technology has radically improved aircraft and flight deck operations resulting in better avionics, navigation, and aircraft performance systems. One direct result of these technology improvements is the considerable training pilots now require learning and mastering the sophisticated flight decks.

GA aircraft are the most common training platform for pilots, and pilots of all abilities generally welcome new GFD technologies. However, traditional training methods for pilots on legacy flight decks appear to be lacking due to the complexity and sophistication of the various GFD subsystems. New training methods are needed to address the new technological components, the incredible density of information available, and the variability of flight deck configurations.

Training on GA aircraft with glass flight deck systems is widely varied, with limited standardization, and almost no formal training requirements in place. The problem identified in this study is the lack of effective training and learning methods for pilots in GA aircraft for mastering glass flight deck systems. Therefore, the researcher investigated if scenario-based training (a mix of training strategies grounded in real world situations and conditions) would improve pilot training and learning on GA glass flight deck systems. The goals of the study included seeking improvements for both flight instructors and pilots in the quality of their training experiences, their learnability experiences, and their resulting knowledge of the use and application of glass flight deck systems. The research addressed research questions regarding the extent of improvement in the overall quality of pilot training experience and the extent of improvement in the pilot’s learnability experience with the use of SBT strategies. It also sought to address what, if any, instructional design improvements might be uncovered or suggested due to implementation of the SBT training strategies.

The researcher designed this study as a single case study using an embedded case design. Exploratory and descriptive strategies were used to investigate SBT on GA glass flight decks at a Midwestern aviation university. Using an SBT approach, a mix of training strategies was used and includes traditional textbook material and classroom lectures, practicing of tasks in a CBT environment, testing of skill sets in a simulated aircraft environment, and application and demonstration of mastery of entire flights in flight simulation devices.

Areas such as new manufacturer designs and developments, extreme operating conditions, touch, gesture, and speech/voice recognition, and others are challenges, barriers, and issues beyond the scope of this study. The newness of this research is also a known concern for this study. While published literature provides considerable documentation on pilots' positive attitudes and perceptions towards using glass flight deck technology, there is relatively little research completed on the usability of GA glass flight deck systems. Little research also appears to exist on alternative training strategies (e.g. SBT) and resulting effects on pilots and flight instructors training experience and their satisfaction with GA glass flight deck systems.

This study is relevant as the review of literature indicates that while pilots have positive perceptions and attitudes on the extent and use of glass flight deck technology in GA training aircraft, they also have concerns regarding learning and mastery of the complex and extensive capabilities of glass flight deck systems found in GA training aircraft. It is significant in that the findings may contribute to a better understanding of best training practices and strategies for pilots and flight instructors as they add the role of systems manager to their overall pilot responsibilities.

Chapter 2

Review of the Literature

Pilot Training

Traditionally, GA pilot training curriculum provided by flight schools and academic programs typically require pilots to complete required flight training in aircraft flight-lines comprised of aircraft 15 to 30 years old (Hahn, 2012). Many training aircraft of the late 1970s through the 1990s are still the primary flight trainers used, and pilot training is completed predominately in these older aircraft configured with conventional round dial instrumentation. Kearns (2007) highlighted that some of the older aircraft have been slowly upgraded with more digital avionics and display systems, and more frequently, newer aircraft with complete glass flight decks (GFDs) are showing up on aviation training flight lines. The FAA (2006) acknowledged that with older aircraft instrumentation, GA flight systems all functioned and looked similar, regardless of the manufacturer. However, newer flight deck technology systems may perform the same or similar functions but may not look or act alike, and pilot interactions with different GFD subsystems is often unique and particular to the specific aircraft model operated (Baxter et al., 2007; FAA, 2006). With the increase in digitally generated flight decks showing up in both older and newer model GA aircraft, pilots are encountering different glass flight deck technology more frequently in their training aircraft when completing pilot training curriculum (Casner, 2008; Hahn, 2012; Kearns, 2007; Mitchell et al., 2009).

Whereas the conventional round dial instrument flight deck has a limited way of presenting flight and navigation data to the pilot, the GFD system of today can present not only the current flight and navigation data, but other valuable information such as historical, trending, forecast, and projected data as calculated by the computer subsystems underlying the glass flight deck technology. Automation of some pilot tasks, or portions of tasks, is also a hallmark of glass flight deck technology, allowing the pilot to assign which tasks the glass flight deck can manage (Mitchell et al., 2009). Typical GFD systems most often include subsystems for GPS navigation, electronic flight instruments, moving map displays, autopilot controls, terrain mapping and avoidance, aircraft systems management, and weather and traffic monitoring (Casner, 2009; Kearns, 2007; Mitchell et al., 2010).

This increase in technological sophistication of the flight deck forces a considerable increase in a pilot's level of training and education to match the level of operating standards necessary to properly and safely fly glass flight deck equipped GA aircraft (Baxter et al., 2007; Mitchell et al., 2009). DeMik et al. (2008) added that with the recent development of the class of aircraft labeled as *very light jets* (VLJs: GA aircraft equipped with jet engines), GA aircraft are now being delivered with an increase in speed and maneuverability found traditionally only in commercial and military aircraft. DeMik et al. (2008) pointed out that typical VLJ operations are done with a single pilot, and single-pilot operations cannot be trained using multi-crew training approaches such as used by the commercial airline industry. The GA pilot will require additional new and comprehensive training opportunities to learn, handle, and master flight in this new generation of aircraft.

Pilots face many learning hurdles while training to master GFD systems. Hurdles include inadequate training and support manuals, changes in flight instructors and training environments, inadequate or incomplete computer-based training programs, and little to no standardization in training curriculum. Casner (2008) and Mitchell et al. (2010) cited surveys noting pilots are often left to teach and train for the proper use of a GFD by reading manufacturer technical and user manuals for the various subsystems, and referencing explanations of functionality from textbooks or third-party training manuals. Harris (2008) underscored the inadequacy of technical manuals and a lack of detailed how-to-use information needed for proper training and learning processes, and reported manuals were often of little use for proper training or learning, instead being relegated to use as a lowly reference manual or dictionary-like resource for definitions and short operational explanations.

Beaudin-Seiler, Beaudin, and Seiler (2008) presented several studies noting that it is common for pilot trainees to experience changes in flight instructors when instructors take new, higher paying jobs flying commercially for the airlines, or as flight instructor work locations change. Hahn (2102) noted in a meta-review of aviation training studies that pilot trainees who learn with different flight instructors can experience a compounding – and often negative - effect on their training and learning efforts. This tends to result in gaps in training, as well as create retraining orientation and currency issues as the new flight instructor-pilot relationship must be built before training can continue to move forward (Beaudin-Seiler, Beaudin, & Seiler, 2008; Hahn, 2012). Kearns (2011) cited reports that additional challenges faced by GA pilots with glass flight deck technology are their limited flight experience, and of having lower levels of flight skills often exceeded by their confidence levels. Given this is the highest risk period in a pilot's early-on training, advanced flight deck technology adds additional training requirements that are frequently elusive and inconsistent (Hahn, 2012).

With the many hurdles pilots face learning GFD systems new training methods are not only necessary, but also critical for pilots to be able to maintain flight safety while successfully using and managing these new systems correctly. Kearns (2011) discussed safety of flight concerns within the context of maintaining proper control and management of the airplane without getting lost or distracted in the processes of manipulating various switches, buttons, and dials. Hahn (2012) and Harris (2008) discussed legacy military training beliefs that real learning only occurs on the job, and the near-impossible and certainly difficult learning environment of present day flight deck training where on-the-job learning conflicts with the higher priorities of flight safety.

Some efforts have been made to create computer-based, user-centered or user-based training aids to improve existing flight instructor and pilot learning and training. Kearns (2011) noted that although some computer-based training systems (CBTs) have been developed for training purposes, most tend to digitally replicate the manufacturer's user manuals, while others break the wealth of glass flight deck functionality down into chapters presented in traditional CBT modular formats. Casner (2008) and Mitchell et al. (2010) pointed out that no formal training requirement on glass flight deck technology of flight instructors is required, and when coupled with no standardization of glass flight deck training curriculum, little opportunity for substantial learning of problem-solving skills needed inside the flight deck can be realized.

Hahn (2012), Kearns (2011), and Mitchell et al. (2009) discussed numerous studies and surveys that identified poor or inadequate levels of training during the transition from conventional round dial flight decks to glass flight decks. Partly a lack of understanding of the computer technology employed, and partly to some extent pilots' computer literacy skills, both these contributory factors seemingly affect the learnability of GFD systems. Baxter et al. (2007) and Mitchell et al. (2009) suggested that pilots need in-depth and specific training in computer literacy in both a) a broader sense of understanding computer-based systems and b) in the narrower sense of the computerized technology of the particular aircraft.

Numerous studies and surveys overwhelmingly identified pilots concerns with ongoing training and transition from conventional flight decks to glass flight decks with strongly worded descriptions of training as being “poorly managed,” “rushed,” “grossly inadequate,” and “insufficient in technical coverage” (Casner, 2008, 2009; Hahn, 2012; Kearns, 2011; Mitchell et al., 2009; Mitchell et al., 2010). Taken within the context of user satisfaction or experience, these descriptions reflected the lack of satisfaction pilots experienced with the glass flight deck transition training completed. Casner (2009) and Mitchell et al. (2010) added that when flight instructor experience and training vary from instructor to instructor, it often had a direct impact on the quality of training student pilots ultimately receive, and directly affected the quality of the pilot’s (user) experience and satisfaction with the training process and mostly in a negative direction.

Harris’s (2008) work reviewed two decades of studies underscoring the importance of structured and standardized training programs for mastering complex human-computer interactive devices. He emphasized many of the studies’ wide ranging positive performance results suggested high-fidelity computer simulations grounded by sound instructional system design approaches results in shorter training times and improved training outcomes marked by enhanced problem solving and critical thinking skills that transfer to the real world. Hahn (2012) and Kearns (2007, 2011) reviewed several studies that suggested the use of scenario-based training methods coupled with simulations and non-technical training approaches that focus not on flying skills but rather active learning (active participation in the learning process), successfully enhanced pilot cognitive and psychomotor skills performance, and improved pilot perceptions of training. Turner and Carriveau (2010) underscored active learning (through scenario-based activities) as fundamental in promoting deeper learning critical to developing higher order critical thinking and decision-making skills.

The FAA, through its FAA/Industry Training Standards (FITS) program recommendations (FAA, 2004), forecasted that traditionally prescribed rote memorization of factual data and many legacy flight training methods (often referred to as maneuver-based training) would need to be significantly supplemented, and in some cases, out-rightly replaced. Craig (2009) and DeMik et al. (2008) emphasized that as a means to provide higher quality flight training, the FAA-identified scenario-based training provides a reasonable training curriculum approach in moving pilots from a place of knowing their aircraft systems to being able to *manage* the glass flight deck, and through improved abilities to critically analyze flight situations, and make sound, correct decisions on how to proceed. In the FAA (2003) published FITS list of program goals, the agency prescribed that future pilot training should be based on a "real world scenario-based, problem solving and case study" foundation (p.4) aimed at improving pilot critical thinking and decision-making skills. While the very scenario-based FAA FITS program goals were proposed and then implemented to improve real world pilot training practices, the literature review did not reveal adequate numbers of studies regarding scenario-based training successes or failures.

Scenario-based Design and Training

As far back as the mid 1990's, usability engineering experts touted the use of scenario-based design techniques for early phases of system development of user-computer devices or products. For example, Nielsen (1993) discussed the benefits of scenario-based design as useful in determining ways in which users will interact with a system. He noted that scenario-based designs are quite flexible, and can change relative to the user's needs, or the design objectives established. Carroll and Rosson (2002) delineated how user needs are more completely discovered and better organized through scenario-based design. They pointed out how user tasks can be better supported by, and integrated into the system, as driven by those user needs, and are typically concrete in application, as opposed to being abstract or theoretical.

Carroll (2000) summarized, in his seminal work "Making Use", that scenario-based design strategies are rooted in "working with real-life, in-context settings" and deliver benefits such as the "highlighting the goals of what people are trying to do with a system, what procedures are adopted (or not) in pursuit of the goals, whether (the procedures are) carried out successfully (or not), and what interpretations people make of what happens" (p. 46-47). Nielsen (1993) seemed to concur, pointing out that scenario-based design techniques are additionally useful as users find it easier to relate to the concrete task-oriented structure of scenarios, as compared to function-oriented system specifics that are often abstract, and often found in system manuals and documentation. Shneiderman and Plaisant (2010) offered that scenario-based designs help in bringing about a common understanding for design goals, and serve to aid in planning of usability testing. These are a sampling of the perspectives that have underpinned the accepted and extensive use of scenario-based design techniques in the development of systems over the past decade.

A simple definition of a scenario might be that it is a story about people and their activities (Carroll, 2000), or a description of what happens when users perform typical tasks (Shneiderman & Plaisant; 2010). A scenario includes actors, actions, and events. It is a story about people (e.g. aviators) carrying out activities (e.g. interactions with glass flight deck systems) and includes information about their goals, expectations, actions, and reactions (e.g. training or flying on glass flight deck systems) and can represent both novice and expert users (e.g. flight instructors and pilots) (Carroll, 2000, Carroll & Rosson, 2002; Shneiderman & Plaisant; 2010). Summarizing Nielsen's (1993) detailed description of a scenario, it is a series of interaction examples with a flow of specific user actions towards some particular goal or result, with concentration on what the user sees, what the user must know, and what the user can do. These definitions and benefits of scenario-based design for user-computer systems can be directly translated to the creation and use of scenario-based training (SBT) concepts. The technique of using scenarios can be transferred to post-system design implementations and may be particularly effective for learning and training with the GFD system.

Scenario-based training (SBT) offers individually-focused opportunities for the flight instructor or pilot to learn and master aviation skills necessary to support the aviation training requirements of modern GA pilots, and in ways that encourage and instill practical application of knowledge and skills learned (FAA, 2006). Utilizing an SBT approach, multiple flight training scenarios and exercises provide pilots situational learning events to master the knowledge and skills needed for real-world situations, but that would be too high-risk, high-stress, or violate safety protocols if attempted in real-world settings. Kearns (2011) described the foundation of scenario-based training as the active participation of the learner in pursuit of knowledge and skills mastery necessary for real-world applications (p. 176-177). The FAA (2006) identified scenario-based training as a training approach that uses highly structured and scripted practice modeling real-world experiences to teach and measure pilot-flight evaluations in an operational learning environment (p. 2). Adding to Kearns' description, Summers et al. (2007) defined SBT further, noting SBT approaches are unique in that they can be tailored to the individual pilot's specific training needs (p. 5).

Through the use of a combination of traditional lecture, flight simulation practice, and real-world exercises, the pilot actively participates in both *part-task* and *whole-task* training processes to construct knowledge and skills according to their own personal interpretations and experiences. When pilot trainees are focused on doing, and reflecting on what is being done, active participation engages higher order thinking tasks that in turn promotes development of critical thinking skills, and more favorable perceptions about training experiences. Mills (2012) discussed considerable meta-study research evidence of active participation in improving students' attitudes of learning environment, increased student achievement, significant improvements in information recall, higher order thinking skills, and deeper learning. Active participation is one of several components foundational to constructivist learning theories.

Summers et al. (2007) noted that through constant use of part and whole-task training and *what-if* scenarios, the flight instructor can engage and expand the pilot trainee's active participation. Kearns (2011) noted that Clark (2003) discussed active participation as a component of the cognitive apprenticeship approach to learning, noting constructivist theorists' beliefs that this promotes positive results in learners' ability to take content knowledge and apply it in building problem solving and critical thinking skills. Kearns (2011) reviewed Saus et al's (2006) study results wherein the use of SBT improved situational awareness of police in high risk, high stress shooting situations. Summers et al. (2007) pointed out properly designed what-if scenario discussions facilitate and promote development of pilot decision-making skills, and help to build judgment, problem solving, and critical thinking skills.

Proponents of scenario-based training methods suggest that SBT promotes improvements in workload management, decision-making skills, situational awareness, and resources management. Hahn (2012), Harris (2008), and Kearns (2011) proffered that critical thinking and decision-making skills – skills that are mandatory in the flight deck – are best developed through a balance of traditional classroom instruction, high fidelity simulation exercises, and on-the-job training. Craig (2009) and Kearns (2011) offered additional discussion supporting Harris's (2008) views on the benefits of higher fidelity simulation training, taking it further by noting that where traditional classroom lecture-based instruction tends to produce mostly declarative knowledge, scenario-based simulation training develops procedural knowledge that is necessary to knowledge transfer to real world situations. Through the use of goal-oriented and role-playing exercises of scenario-based training curriculum, numerous studies have shown improvement in pilot learning times, and enhanced overall pilot performance within the flight deck (Craig, 2009; FAA, 2004, 2006; DeMik et al., 2008; Hahn, 2012; Harris, 2008; Kearns, 2007, 2011; Summers et al., 2007).

Usability: Issues of Learnability and User Satisfaction

Pilots using complex glass flight deck systems are subject to sophisticated and highly visual and textual displays of an incredible array of information. Visual displays are loaded with pictorial graphics, icons, textual data, animations, and moving imagery. Among the problems uncovered in a review of the literature, use of such complex and information dense systems revealed issues of mode confusion, withdrawal of attention from primary tasks, distractions due to complex menu systems, aural warnings and interruptions, task-to-task transition problems and recovery, and visual discomfort and fatigue (Baxter et al., 2007; Combefis & Pecheur, 2009; Jensen, Skov, & Thiruravichandran, 2010; Villaren, Coppin, & Leal, 2012; Vinot & Athenes, 2012). These researchers pointed to safety, situational awareness, and workload management – all critical aspects of the flight environment – that were substantially reduced or negatively affected resulting from the pilot's limited ability to use the systems properly.

Villaren et al. (2012) reviewed various studies of complex digital electronic and computer-based systems such as found in aviation and aerospace systems, observing the effects of the highly temporal dynamics of managing tasks and task sets. They addressed the temporal aspects arising between primary and secondary tasks. Focusing their own research on the complex systems of aircraft glass flight decks and air traffic control systems, they sought to address the competing demands the pilot faces, and the nature of dealing with highly dynamic tasks within the glass flight deck. Their results underscored previous studies' recognition of the potential for loss of situational awareness due to the frequent changes of a given situation within the same flight segment as a result of task management, surprises, interruptions, recovery efforts resulting from task switching, and divergence between task sets.

Combefis and Pecheur (2009) looked specifically at mode confusion problems arising from usability issues surrounding task executions. Mode confusion is defined as a problem resulting from a pilot thinking the system is doing something when in fact the system is doing something else. Within usability research circles problems that occur when a system behaves quite differently than the user expects have been labeled *automation surprises*. Combefis and Pecheur (2009) reviewed examples of glass flight deck automation within aspects of the flight environment that created unexpected or surprising actions and lead to mode confusion. They concluded that pilot experiences and satisfaction were less than satisfactory, and current usability research must evolve and continue to improve in uncovering and dealing with automation surprises, as it is becoming more routine and common place for humans to interact with more large and complex systems. They discussed results from their study that prompted them in proposing formal rigorous and systematic techniques for generating systems models matched to the pilots' expectations, and identified ways their systems models might reduce automation surprises and mode confusion problems, while improving pilot satisfaction.

Vinot and Athenes (2012) addressed issues of visual discomfort and fatigue resulting from the traditional way information is displayed on glass fight deck screens. Through their research they identified abrupt visual transitions inside and out of the flight deck, extreme lighting conditions, constant adaptation to varying levels of brightness, multiple displays and viewing angles, overlapping of graphical elements, and poor and varied use of digital fonts as contributory to numerous learnability and experiential problems pilots tend to have. Their research efforts addressed the importance of continued development of new typographical fonts and graphics presentation layouts to mediate these kinds of usability issues, to reduce learnability issues, and improve pilot experiences and satisfaction.

Page (2009), in a study of how microelectronics has brought benefits to certain high-tech products, noted that users reported they found benefits in the usefulness of new functionalities, but the benefits were also accompanied by difficulties with learnability of the new capabilities to a point where the added complexities were detrimental to the usability of the product. Page (2009) used the term *feature creep* for this phenomenon, and noted a common result was that most users reported learning only basic operations to meet basic needs instead of mastering all the functionalities the advanced microelectronics provided. Mitchell et al. (2009) identified pilot perceptions noting concerns with the complexly high tech flight decks citing their experiences in discovery of glass flight deck design problems and shortcomings occurring while in use in daily real-time operations, adversely affecting pilot satisfaction with the sophisticated GFD systems. Pilots reported resorting to learning only the minimum buttons, switches, and options needed to fly.

For the traditional flight instructor, non-standardized training methods tend to make their instructional training processes for their pilots a limiting factor in just how well those pilots are enabled, let alone required, to grasp the capabilities of GFD technology. Proper and complete learning of glass flight deck systems is adversely impacted. For example, Casner (2008, 2009) concurred with Mitchell et al. (2009), that too frequently, simple operations of the glass flight deck technology become the primary tasks taught, often with the main objective of teaching the pilot to focus on which button or switch to press at a given time, or when to change a dial or alter a setting for a specific information view to be displayed.

Training by flight instructors in this way translates into downstream pilot training that typically results in learning to utilize only a substantially small portion of the overall capabilities the glass flight deck offers. Casner (2008, 2009) and Mitchell et al. (2010) reviewed pilot reports that learning the various interfaces that make up the glass flight deck are problematic when the understanding of the individual subsystems is not clear, and that many features go un-learned due to the complex interrelationships between subsystems. They pointed to pilot reports of issues with learnability and satisfaction that seem to stem from the complexity and wealth of menu options and information presentation on GFD systems. These and similar studies reported that pilots generally have concerns resulting from perceptions that glass flight decks are quite complex, and require greater amounts of flight experience to effectively operate (Casner, 2008, 2009; Hahn, 2012; Mitchell et al., 2010).

Casner (2009) and Hahn (2012) described studies documenting flight instructors perceive the complex glass flight deck as a barrier to learning more than just its basic operations, with the pilot often missing proper understanding of important and critical information alerting systems imbedded in the systems and intended to improve the safety of flight. Without a clear understanding of how to interpret the valuable warning and alerting systems information, pilots may not learn the necessary troubleshooting and failure response strategies necessary to handle such situations (Casner, 2009; FAA, 2004). Mitchell et al. (2009) reviewed pilot surveys wherein pilots cited concerns of difficulties in detecting system faults and malfunctions, the potential for misleading or faulty data, and the resulting lack of confidence in ability to rely on the flight information presented.

Dense, highly compact areas of detailed information can present a visual information overload. Jensen, Skov, and Thiruravichandran (2010) noted study results of decreased automobile driver performance using highly sophisticated visual GPS moving map systems such as similarly found in current GA aircraft. Their study revealed that the considerable increase in eye glances between looking outside the vehicle and inside at the GPS system, led to a substantial decrease in driving performance. This decrease resulted in an increase in driving regulation and rule violations, an increase in the risk of accidents, and an overall decrease of safety. Le Pape and Vatrapu (2009) presented similar study results underscoring difficulties arising with human-computer interactions in complex domain environments where sophisticated electronics are mixed with extreme environments such as high performance aircraft or space flight. Study results showed participants experienced considerable cognitive load issues, resulting in the increase in probability of making critical – and potentially fatal – errors, and a decrease in overall safety executing their tasks. They postulated that considerably more human-computer interaction research is required to address the unique constraints of complex domain environments on human-computer interactions and how differing cognitive styles impact those interactions. They argued that future usability designs must take into account the cognitive style differences in complex domain environments to mitigate increasing cognitive load and the probability of making errors.

Similarly, considerable survey data indicated that a high number of flight instructors foresee significant problems using glass flight decks when training new pilots due to the potential for safety of flight concerns due to learnability problems introduced by the extensive complexity and sophistication of glass flight decks (Baxter et al., 2007; Casner, 2008, 2009; DeMik et al., 2008; Mitchell et al., 2010). DeMik et al. (2008) reviewed studies on learning and training concerns with Very Light Jet (VLJ) aircraft that revealed key issues with GFD systems exist. These include flight deck resource use and management, low flight hours logged in VLJs, difficulties with the use of advanced jet avionics, monitoring and recognizing systems warnings and fault monitoring alerts. They underscored how problematic this can be as these difficulties become exacerbated in single pilot operations where the entire flight workload falls to the single - and the only - pilot flying the advanced aircraft.

Hahn (2102) and Mitchell et al. (2010) summarized flight instructors concerns with the need to have a full understanding of the overall integration of the various flight subsystems, and that a clearer understanding of the glass flight deck requires the typical pilot to log many flight hours in varying flight situations and conditions just to gain the wider perspectives and experiences needed to fully and properly utilize the entire GFD system. These researchers argued for better training for understanding of secondary task executions that the various flight subsystems provide, in support of the primary task of flying the aircraft. They posited that perhaps only with considerable flight experience in varied flight conditions can secondary tasks be fully integrated in the pilot's glass flight deck experience. Casner (2009) and Mitchell et al. (2010) found that more flight time and experience are perceived as necessary by pilots to maintain proficiency in a glass flight deck, including recurrent training. Casner (2008) outlined surveys noting differences in pilots' opinions and attitudes as to what amount of initial training pilots should have on GFD systems, and Kearns (2011) addressed whether learnability issues of complex and sophisticated glass flight decks are limiting factors affecting training. Kearns (2011), in agreement with Casner (2009) and Mitchell et al. (2010), pointed to differing perspectives on how much and when advanced and recurrent training should be completed.

Secondary tasks involving using glass flight deck subsystems technology can result in the withdrawal of attention, diversions from completing primary tasks, the creation of competing distractions, etc., all which serve to induce safety risks (Baxter et al., 2007; Le Pape & Vatrapu, 2009; Jensen et al., 2010). Le Pape and Vatrapu (2009) pointed to complex environments such as aviation, medicine, nuclear energy, or space, as examples of domains most often characterized and bounded by conditions of stress and risk, and as environments inherently intolerant of user errors. They emphasized that even though traditional usability approaches have grown in diversity and scope along with ubiquitous computing, safety is still a fundamental goal of usability research. They proffered usability research investigating complex domain environments such as these are limited and often only application or context-specific.

Chilana, Wobbrock, and Ko (2010) reviewed the literature on the use of traditional usability evaluation methods commonly employed for conventional web sites and graphical user interfaces. They uncovered little research on conventional usability evaluation methodologies being used successfully by usability professionals, instead finding current usability approaches as too contemporary and not comprehensive enough for evaluating complex domain-devices such as found in the industries of aviation, aerospace, medicine, nuclear energy, and others. These researchers found that usability practices in the complex domains have had little to no prior research or investigation. Their study results generated considerable survey data supporting the concerns of inadequacy, applicability, and suitability of common usability approaches held by numerous field experts from those complex domains, concerns that appear to be well founded. They offered several best practices to begin understanding how complex domains affect usability practices, ways usability professionals might begin to address remedying inadequate usability methods currently employed, and to develop new usability evaluation strategies for the next generation of usability professionals working with complex domains.

Qualitative Case Study Research

The literature review uncovered research studies of varying types. Most studies were completed by looking at developing dominant qualitative perspectives of pilot perceptions, experiences, attitudes, and satisfaction of their use of glass flight deck systems. Few studies pursued traditional quantitative experimental approaches, instead choosing to look at simple statistics of percentages and averages of pilot participant responses (Casner, 2008, 2009; Mitchell et al. 2010). Whether or not explicitly defined in the study, many reports appeared to follow a case study approach, by looking at different groups of pilots studied (e.g. airline pilots, commercial pilots, flight instructors, pilot trainees, etc.) (Casner, 2008; Craig, 2009; Mitchell et al., 2009, 2010). Most study reports were presented as qualitative research studies.

The rationale for this qualitative study as a single case approach is consistent with Stake's (2006) and Yin's (2014) perspectives on case study research. Stake (2006) proffered case study research was developed to understand the experience of real life cases operating in real life situations. He stated that qualitative case research focuses on the ordinary practices of natural or real-world habitats, and is best for reflection on complex, situated, problematic relationships such as found in academic domains. Better than experiments or surveys, qualitative case study research, when designed properly, captures the complexity of the case under study, along with relevant changes that occur over time, while paying full attention to the contextual conditions of the case (Stake, 2006; Yin, 2014).

Yin (2014) offered that case study methodology is well suited to answering research goals and questions of what, how, and why where the phenomenon under study is a contemporary event or situation in a real life context. He emphasized qualitative case studies are an appropriate research method used in "social disciplines and practicing professions" (p.4) such as psychology, sociology, business, and education. The goals of this study were established to gain a better understanding how and what, if any, improvements in pilot knowledge and perceptions of their learning and training experience on the use of GFD systems, are achieved through using scenario-based learning and training strategies. These goals and the specific research questions as posited were investigated through a carefully organized and structured qualitative case study design, utilizing a single case approach.

Case study research can be based on either single or multiple case study design approaches. A qualitative single case study can be defined as a research study that is bounded by context or situation, by a specific group or event in which there is shared natural or common characteristics or conditions (Marshall & Rossman, 20111; Stake, 2006; Yin, 2014). Stake (2006) defined a single case research study as focused on a single group, noun, or thing such as in teachers, schools, or students. Yin (2014) offered that a single case study is considered analogous to a single experiment. He suggested single case studies as useful for testing or exploring theories or concepts of interest especially when used as an initial study for follow-on subsequent studies, or for future multi-case research. In contrast, multiple case studies are defined as studies of a particular collection of cases often with the objective of understanding the similarities and differences between the cases, and the relationship to the overall phenomenon under study (Stake 2006; Yin, 2014). The single-case study approach was appropriately selected for this study.

Yin (2014) further delineated single case studies into the two different types of *holistic* and *embedded* designs. He described holistic designs as studies where only the whole case is under study, is holistic or global in nature, or where no logical subunits are identified within the case (Figure 1, Case A). He defined embedded case design as studies wherein attention is not only given to the case, but also is given to subunits in the case. The subunits within the case are analyzed and may be related to the overall phenomenon of the case under study (Figure 1, Cases B and C). Yin's (2014) discussion on embedded case designs, and the relationship of the units to a given case can be represented graphically as shown in the Figure 1.

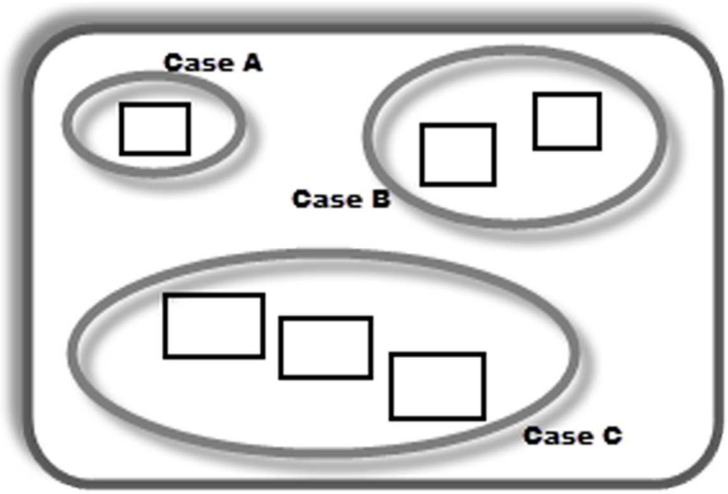

Figure 1. Holistic and Embedded Case Study Designs. Within the context bounded by the rectangle, different Cases may exist. A square within any given Case represents a single Unit of Analysis. Cases with more than one Unit of Analysis are considered embedded designs (Cases B and C).

While both types of single case study designs each have their own strengths and weaknesses, and advantages and disadvantages, Yin (2014) offered that embedded designs are effective for maintaining focus on the case under study. He also noted embedded designs help to combat issues with study "slippage" when holistic case study become unduly abstract or when the nature of the case shifts during the study, both of which are weaknesses of holistic designs. Yin (2014) noted further that as long as the operational focus on subunits does not interfere with the researcher returning to analyzing the larger unit – the case – the benefits of embedded designs outweigh holistic designs. It was with these guidelines in mind, and the overall desire to gain a better understanding of, and the potential to create new knowledge, on the issues pilots face when learning and training on GFD systems. In this way, the study was structured as a qualitative embedded single case design, looking at the two subgroups of pilots and flight instructors.

What is Known and Unknown

What is Known

As supported by the results of the literature review, further research on potential improvements in the instructional systems and training methods for GFD systems is reasonable. The researcher sought to understand to what extent scenario-based training may impact pilot knowledge, as well as to explore if improvements in the learnability of, and pilot satisfaction with glass flight decks can be attained. If the sum total of the learning and training experience can be improved, then this study served to shed more light ways pilot training on GFD systems can be enhanced, and how their enhanced training and knowledge might be beneficial instructionally downstream for other pilot trainees.

The extent of research on pilot attitudes and perceptions using glass flight deck technology in GA aircraft is limited. Only in the past decade has research been completed on GA glass flight deck technology usability and training issues. Today, most GA aircraft are being manufactured and delivered to the GA market with advanced flight deck technology, while much of the existing GA aircraft used in training fleets have undergone some degree of technology-based avionics upgrades. The result is that pilots are instructing and training with GA aircraft fleets that are often a mix of new aircraft with integrated glass flight deck technology and older aircraft with flight deck environments with varying degrees of advanced flight systems components.

The FAA (2003) emphasized the fact that new GFD systems that perform similar functions do not necessarily look alike nor function the same, and pilots interactions with these systems may be totally different from aircraft to aircraft. Numerous government and private research studies have indicated that legacy pilot training approaches may not be adequate for teaching proper use of these new GFD systems. The FAA (2006) acknowledged the new small GA aircraft with advanced avionics and glass flight deck systems technology no longer neatly fit with currently approved FAA training programs, and recognized that although the positive improvements in flight safety and situational awareness are a benefit of these technological advancements, new glass flight deck technologies are being introduced faster than FAA training resources can respond or keep up. To address the limitations of legacy pilot training approaches, the review of the literature seems to offer the conclusion that new flexible and adaptable approaches to learning are needed to address the new GA flight training environment that GFD technologies have brought to the world of flight instruction.

While no absolute, comprehensive solutions were uncovered in the literature review, the support for, and use of, scenario-based training was found to be a plausible instructional approach to teaching and learning to use glass flight deck technology. As the benefits of scenario-based design for user-computer systems can be directly translated to the creation and use of scenario-based training (SBT) concepts, it follows that scenario-based training may offer similar benefits in learning and training on GFD systems. The technique of using scenarios added to the instructional design process for particular non-technical areas of pilot training has shown to be effective. The literature review offered examples and applications where scenario-based training approaches may show a positive impact on both learnability and pilot satisfaction issues with glass flight deck technology. In the few and limited studies available, the use of scenario-based training has shown to improve pilot performance on certain non-flight tasks. Of particular note were increases in knowledge transfer on complex glass flight deck concepts, and a direct and positive impact on pilot development of critical thinking skills and aeronautical decision-making skills.

The FAA (2006) seems to support this perspective noting in several FAA training publications that flight instruction will have to change to include examples of real-world tasks, with pilots trained to solve glass flight deck systems problems in addition to flying the airplane. Scenario-based training involves active participation by the pilot trainee immersed in real world tasks and in examples of real flight operations. Summers et al. (2007) pointed out that instruction founded in whole-task training and *what-if* scenarios engages and expands the pilot trainee's active participation. In their work with SBT, Craig (2009) and Kearns (2011) contended scenario-based simulation training develops procedural knowledge that is necessary to knowledge transfer to real world situations. Through the use of real-world scenarios based on actual tasks the pilot should expect to experience in the flight deck during actual flight operations, training opportunities can incorporate SBT early-on to insure the pilot is exposed and trained to handle them as they might occur in the real world. Additionally, it follows that application of organized and rigorous scenario-based real-world tasks may further inform future development and improvements in pilot training strategies and methodologies.

Hahn (2012), Harris (2008), and Kearns (2011) proffered that critical thinking and decision-making skills are best developed through a balanced combination of traditional classroom instruction, high fidelity simulation exercises, and on-the-job applications. Summarizing the perspectives of these various proponents of scenario-based training, one might suggest that training programs combining the use of typical classroom education materials (lectures and textbooks use), computer-based training sessions, and flight simulation of real world events, may have great potential to improve modern glass flight deck training. It may well prove to be an enhancement upon traditional training approaches for pilots transitioning to more advanced technology GA aircraft.

What is Unknown

Areas for future research seem to fall into distinct areas. Researchers pointed out that historically the cost to develop and build a completely new GA glass flight deck system has been proven prohibitively high. Only through recent technological innovation has the manufacture of GFD systems slowly become more economically feasible. Much of the existing GA glass flight deck technology in use today is patterned off commercial jet airline subsystems but redesigned and retooled for use in GA aircraft resulting in mixed variations of glass flight deck technology on existing GA aircraft. Coupled with new GA aircraft being delivered with increasingly advanced glass flight deck technology, existing flight lines of older aircraft require new training approaches to be matched to the use of the aircraft available for flight training. The focus for this study on both the usability constructs of learnability and user satisfaction of GA glass flight deck systems and on pilot training methods for GFD systems reflects two of the primary research areas for the immediate future.

The primary areas of focus on usability and training research need to address the current problems and issues with learnability and pilot satisfaction as outlined in this study. Kearns (2011) proffered that focus and emphasis on developing better comprehensive training methods should be directed at building scenario-based training strategies to address these training concerns of pilots on the proper use and application of the newer advanced glass flight deck technologies. In turn, scenario-based training methods may also serve to inform manufacturer designs of future GFD systems.

Scenario-based training appears to offer flexibility and adaptability to the individual pilot needs, as well as addressing the variability and mix of glass flight deck systems in differing aircraft make and models. Scenario-based training may also provide a foundation for developing and constructing pilot knowledge on the complex inter-relationships of the various glass flight deck technology subsystems. As pilots will have to become managers of these subsystems, in addition to being pilots controlling aircraft in flight, this aspect of glass flight deck training will become fundamental. Scenario-based training methods should also be investigated as a comprehensive instructional approach for each of the varying levels of pilot training from basic GFD systems operations to advanced flight management and navigation, and to currency and transitional training requirements that all pilots face in an ongoing fashion. Additional primary research might address and develop a series of modernized learning and training *best practices* for glass flight deck training that might be approved and instituted as FAA-authorized training curriculum for the future.

The literature review uncovered many other areas where further research is needed – most of which are well beyond the scope of this study as designed. Aspects of human factors, psychology, and ergonomics include issues such as visual fatigue, cognitive styles adaptation, pilot workload management, communications and information overload, interruptive messaging alerts, and automation surprises. Future research will also need to investigate better comprehensive ways of improving pilot comprehension and satisfaction of GFD systems technology, consider newer technologies available in common computing environments, address ways to incorporate adaptability into systems to meet individualized user preferences for displays and systems interface complexity for various in-flight applications. Research should address potential benefits of adaptive-intelligent agents to aid in managing the glass flight deck, and ways to provide improved interruption alerts and handling of automation surprises.

A growing and unique branch of human factors in aviation involves ongoing assessment and monitoring of pilot actions within the glass flight deck by intelligent computer monitoring systems. Research is already ongoing with the use of computer-based adaptive and intelligent assistants or agents to monitor and track user actions is growing in a number of high-risk, high stress environments as found in space, marine, nuclear, and military warfare applications (Baxter et al., 2007; Stanton et al., 2009). As applied in the flight deck, the adaptive-intelligent agents might compare pilot actions against a database store of expected behavior and actions or predictive situational problems, and then provide alerts or warning to the pilot of deviations from expected actions as they occur (Cahill & Losa, 2007; Stanton et al., 2009).

Last, but perhaps most importantly, is the need for future research to evolve and expand the techniques and methods of current usability testing approaches to meet the demands of complex domains such as found in aviation, space, nuclear energy, medicine, and others. Chilana, Wobbrock, and Ko (2010) and Le Pape and Vatrapu (2009) noted challenges exist in the application of current usability testing techniques to these complex domains. Mancero, Wong, and Amaldi (2007) discussed the importance of addressing *change* or *inattentional blindness* (a failure to detect changes in information within one's visual field) often found in complex domains such as the glass flight deck environment. Chilana, Wobbrock, and Ko (2010), Le Pape and Vatrapu (2009), and Maybury (2012) suggested new usability testing approaches need to be developed through combining the depth of knowledge of complex domain experts with the breadth of knowledge of highly experienced usability professionals. These researchers also pointed to the need for the development of formal partnerships between usability specialists/organizations and groups of complex domain experts acting as consultants in order to establish and build credibility with developers, designers, and manufacturers of technologically advanced aviation and aircraft systems. It is possible that usability engineering professionals experienced in Carroll's (2000, 2002) scenario-based design techniques may help bridge the gap between the complex domain experts and ongoing usability testing efforts.

Summary

Traditional pilot training aircraft and equipment have evolved over the past two decades and now many GA training aircraft have a mix of legacy technology and modern computer-based glass flight deck systems. Traditional pilot training curriculum has not evolved to keep up with technological improvements in aircraft and equipment. Reliance on legacy pilot training approaches appears to be less effective as newer flight deck technologies have introduced many new configurations and adaptations to existing flight training aircraft. Pilot training and education requirements have increased and must now meet new levels of operating standards for the complex and sophisticated flight deck environment.

Extensive literature exists documenting the various learning and training challenges technically advanced aircraft (TAA) present. Inadequate or incomplete training manuals and CBT programs, lack of standardized training curriculum, flight instructors changes, and limited analog-to-glass transition training materials are just a few of the challenging areas. This study included review of one possible training approach (SBT) that may address some of these training challenges.

Scenario-based training emphasizes real-world oriented training opportunities for the flight instructor or pilot to learn and master aviation skills necessary to support the aviation training requirements of modern GA pilots, and in ways that encourage and instill practical application of knowledge and skills learned. These training scenarios are based on examples of flight environments that pilots will experience in the real world. Proponents of scenario-based training tout higher order critical thinking and decision-making skills are improved through realistic practice of the tasks and flight skills used in real-world situations. Studies show overall pilot learning and performance has also shown to improve with SBT.

The researcher also looked at the usability of glass flight deck systems with respect to pilot learning and training experiences. The usability attributes of learnability and user satisfaction were measured from both the pilot and the flight instructor perspectives. Following a qualitative single case study design, the researcher investigated the learning and training experiences of pilots and flight instructors as they learn to master a glass flight deck system using an SBT approach. The case study was bounded by the Midwestern aviation university. Throughout the execution of the study, qualitative data were collected and then analyzed. An embedded case study design was used, and pilots and flight instructors were reviewed as separate subgroups within the case's boundary.

Chapter 3

Methodology

Overview

The aim of this study was to investigate pilot perceptions and attitudes towards scenario-based training as a possible solution to the reported concerns with training experience, satisfaction, and learning methods when mastering GA glass flight deck systems. The goals included investigation of specific questions regarding potential improvements in the pilot's learning and training process, to the learnability of glass flight deck systems via structured, focused scenario-based training strategies, and the impact on pilot training perceptions, experience, and satisfaction with glass flight deck training accomplished via scenario-based strategies.

Key components of this study included an in-depth investigation of the training of multiple pilots, examination of their use of GFD systems within a natural training context, the use of multiple data sources, with an emphasis on qualitative data collection, analysis, and interpretation of the results. A qualitative case study research design was implemented to seek answers to the research questions, and was used to determine if the goals of the study can be met with the suggested instructional design changes in the training and learning procedures.

The following research questions for this study were:

1. To what extent does the quality of user learning and training experiences improve by utilizing a scenario-based training approach to the use of glass flight deck systems by pilots?
2. To what extent does the quality of the learnability experience of pilots utilizing a scenario-based training approach improve their satisfaction with, and perceptions and attitudes of their use of and reliance on glass flight deck systems?
3. What, if any, are additional instructional designs improvements in glass flight deck training suggested or found through implementing the changes in the training methodology as proposed?

Study Design

Case Study Research – Philosophy and Rationale

The qualitative research design for this study was based on an embedded design single case study approach using both exploratory and descriptive strategies. Qualitative case study research strategies allow researchers to delve deeper into the meanings of experiences so as to better understand those experiences (Marshall & Rossman, 2011; Munhall & Chenail, 2008). Creswell (2014) outlined qualitative case studies as designs of inquiry in which the researcher completes an in-depth analysis of the case with focus and emphasis on processes or activities of one or more individuals.

Case studies may exhibit a dominant strategy (e.g. explanatory, descriptive, exploratory, etc.), but case study strategies are not mutually exclusive. Often a mix of strategies may be used to great benefit (Lazar et al., 2010). The importance of developing an in-depth understanding the meaning of real-world situations via case study research is central to this study, and so a qualitative case study was the preferred strategy as the researcher is investigating “a contemporary phenomenon” (e.g. this case study) “within its real-world context” (Yin, 2014, p. 16).

Embedded Case Study

This case study research was based on an embedded case study design wherein multiple subunits of the case are analyzed. The case study involved the in-depth investigation of a small number of pilots in the Midwestern aviation university glass flight deck training program. The case was bounded by the aviation program department and involved only undergraduate students enrolled in a professional pilot degree track within the department’s program. Adapting the original Figure 1, this study’s embedded design is graphically represented as shown in Figure 2.

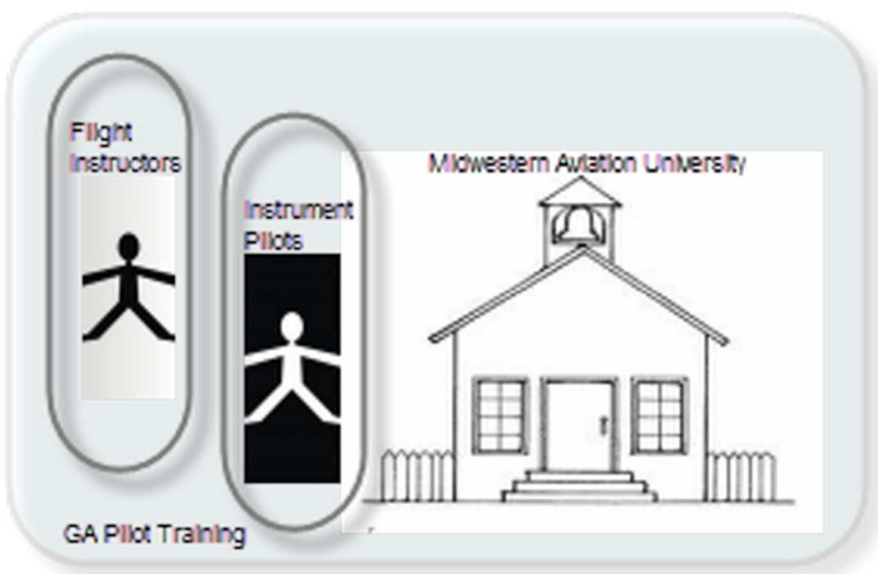

Figure 2. Two Pilot Subgroups: Analysis within the Larger Single Case Study – an Embedded Design. Within the context of GA pilot training, this research study is an Embedded Case design bounded by the Midwestern aviation university department. The Flight Instructor and Instrument Pilot groups make up the two Sub-units of Analysis within the Case.

Common to most higher education undergraduate aviation bachelor degree programs, the professional pilot degree program takes approximately four years to complete. Key components of this study included the in-depth investigation of multiple pilots and an examination of their experiences learning and training on GFD systems within an established training context, the use of multiple data sources, and an emphasis on qualitative data collection, analysis, and interpretation of the results.

Exploratory and Descriptive Strategies

Exploratory strategies were used for this study and aimed at observing how pilots currently accomplish glass flight deck tasks, use the available glass flight deck systems, and react to problematic situations. Through descriptive strategies, the researcher also sought to depict what impact scenario-based training has on the learnability of glass flight deck systems training and pilot knowledge and training experience and satisfaction. This study served well to aid the researcher in interpreting the important issues and learning complexities of glass flight deck systems training in a real-world pilot training environment.

Figure 3 is a graphic depicting the stages of the study. A solicitation for participants was sent out. From the pool of respondents, participants were selected based on the pilot criteria identified in the section outlining the participant selection process, and informed consent forms were signed. In the orientation session, participants were reminded of the study goals and objectives, and all pilots were given a demographic profile and attitude questionnaire to complete. The two training phases followed, and a post-training session and attitudinal questionnaire were completed as a group.

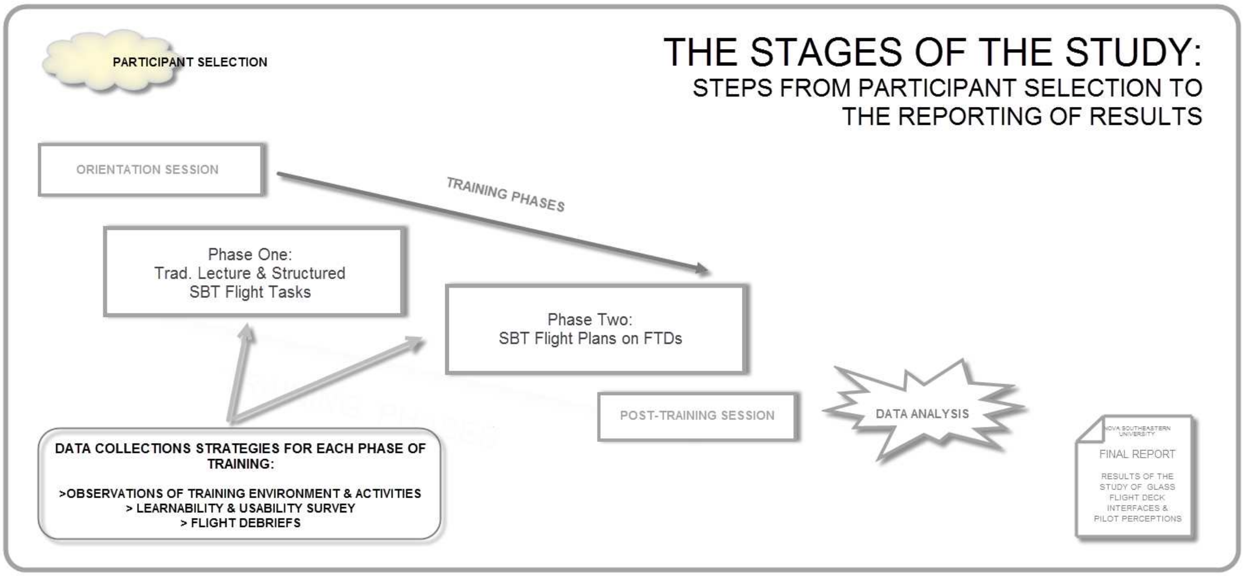

Figure 3. The Stages of the Study: Steps from Participant Selection through Training Phases to Analysis of the Data and Reporting the Results

It was projected the orientation, all training phases, and the post-training session would take approximately three days to complete. The final two stages of the study involved considerably more time due to the amount of data collected. Following data analysis, the results of the analysis were written, and a concluding discussion of the research study was made.

Participants

Two groups of participants were used for this study. Tenured faculty and staff at the Midwestern aviation university comprised one group, and participated by delivering the training content and managing the training processes throughout the training phases. Considered expert aviation instructors, the faculty staff chosen carry full instructor certification according to FAA regulations. Their certifications are current and meet all FAA requirements for flight instructor training in all GA aircraft environments. They additionally served as sources for member checking and peer reviews or debriefings.

The second group of participants in the study is the pilots. These participants were chosen for their pilot training experience and background, and their current pilot profile. They were the recipients of the training regimen and are central to the study's execution and results. This group of participants were separated into two subgroups – one subgroup being the instrument pilots and the other subgroup the flight instructors. Solicitation of potential pilot participants was made via an email sent to all students enrolled at the Midwestern university aviation department's degree programs. Multiple copies of a single page flyer were also hung throughout the aviation department's facilities offering details on participating in the research study and an invitation on how to get additional information and apply. A copy of the information used in the email and flyer protocol is provided in Appendix D.

Pilot Participant Selection and Profile

The researcher selected pilot participants specifically for their similar characteristics of the larger group of pilots as reported in the literature. Additionally, this group was representative of other aviation college or university pilot trainees as found throughout higher education institutions' aviation training programs in the United States. The group of participant pilots included eleven individuals for this study, given the projected amount of time that was to be spent with each participant pilot. Participants were recruited by the researcher from the larger overall group of student pilots within the Midwestern aviation university from the overall larger group that were currently pursuing instrument and flight instructor privileges. Once selected, the participant group were separated into two subgroups – or subunits – with seven as instrument pilots and four as flight instructors.

Particular to this study, instrument pilots were defined as pilots with a current private pilot license, and were studying and pursuing the typical phase of pilot training and certification known as an *instrument-rating* as defined by FAA regulations. Flight instructors were defined as those pilots who, at a minimum, were already pursuing, or held a current flight instructor certificate as issued and defined by the FAA. Under FAA regulations, certificated flight instructors are authorized to train pilots, on both the ground and in the air, for a variety of certificates including private, instrument, commercial and flight instructor licenses and ratings. Bounding the case further, this sub unit grouping insured the scope of the data collected were restricted to the case-specific data acquired through the scenario-based training methods, and from being tainted by external data outside of the case and context.

Of significant importance was the controlling for differences between participants in order to avoid adverse impact on study analysis and results (Creswell, 2012; Gay, Mills, & Airasian; 2006; Marshall & Rossman, 2011). Steps were taken to insure participants of each sub unit were as homogeneous as possible through closely matching participants in a number of areas. This included levels of past training completed, certifications achieved, and current training phases they were in as noted above, but also included other experiential aspects such as total flight hours flown, types and makes of aircraft approved to fly, overall exposure to GFD systems, and specific exposure to glass flight deck training. These efforts helped to insure the sub units were as alike as possible prior to employing the scenario-based training methods used.

Participant Protections – Ethical Considerations

Participants were fully informed as to the nature and intent of the study. Special attention was paid to the data collection efforts (e.g. observations, questionnaires, surveys, flight debriefs, and other physical documentation) the researcher utilized in working with the participants. This occurred by using a formal 'solicitation to participate' that each participant selected received. A paper-based informed consent form was reviewed and executed insuring their understanding of study protections and participation expectations.

Participants were insured of absolute protection against physical and emotional harm, that no deceptive practices would be used, and insured of the strict maintenance of privacy and confidentiality throughout the study. Institutional Review Board (IRB) approval was sought from both educational institutions of which the researcher was a current member. Both institutions granted full IRB approvals for the researcher to conduct the study as conceived.

Concerns with regard to the anonymity or identification of the participants were weighed appropriately. Participants selected a pilot call sign of their choosing – their privately coded substitute identity. Created by the participant during the orientation session, the pilot call signs followed each participant through to the end of the study. Pilot call signs received the utmost confidentiality and remained private amongst the researcher and all participants. Via the use of the pilot call sign, each participant's natural name and identity were protected and anonymity was insured. Pilot call signs are the equivalent to a confidential coding system as might be used to de-identity any other data set from disclosure, etc., such as attained from cryptic or random identification coding schemes.

Given the fact that participants are part of an official training regimen approved by a United States federal agency, records and results remained anonymous for the benefit of the participant. While the suggested new training processes of the case are not controversial, the individual results of the training process potentially could have had an impact on a participant's pursuit of licensing and certification under FAA rules and regulations. The researcher committed to complete the anonymity of all participants. Concerns of researcher time and process requirements for identity conversion did exist but were not significant. Readability of the final case study was not overly impacted by the identify conversion process, and the researcher believes overall case study quality was not adversely affected in any way by these concerns.

Environment and Setup for the Study

Ensuring the environment was as consistent as possible for all participants was another important aspect of this study (Gay et al., 2006). The setting for the study was a Midwestern aviation university focused on training professional pilots headed for military, corporate, or commercial pilot careers. The geographic setting was strictly limited to the university facilities where professional pilot training currently takes place. The study took place in laboratory classrooms, computer labs, traditional lecture facilities, and simulation laboratories.

Tenured faculty and staff were employed for delivery for both traditional classroom and SBT training methods and occurred in the same fashion and places established by the study protocols and procedures. Consistent times for training, learning, and practice sessions were established for all the meeting places. Learning and training materials utilized were the same for all participants. Use of the various types of equipment (computer hardware and peripherals, computer-based training programs, procedure trainers, and aircraft simulators) took place in the same location and facilities for all participants. All training, learning, and practice activities were delivered in identical fashion to all participants. An established and consistent environment further cemented the boundary of the environment, and improved the overall reliability of the case findings.

Data Collection

Data Collection - Multiple Sources

Data collected in case studies can be referred to as case study evidence (Yin, 2014). A major strength of case study research is the variety of evidence sources available. The researcher placed primary emphasis on qualitative data collection and analysis through data collection strategies of observation, surveys, and flight debriefs. A limited amount of quantitative data were also obtained due to the nature of the demographic, profile, and experiential surveys /questionnaires used. Meta-analyses of case study research completed suggested that research authors have rated case studies with multiple sources of evidence as 'higher in quality' than those without (Marshall & Rossman, 2011; Yin, 2014). Each of the data collection strategies used for this study are presented in Table 1 accompanied by the type of data each strategy produced.

Table 1

Data Collection Strategies

Data Collection Strategy	Strategy Results
Observations	• Records of participant behavior, actions, and dialog of events • Notes on physical setting, researcher hunches, impressions, and items on which to follow up • Records of casual observations of the training process and the overall training environment
Usability/Learnability/Experiential/Demographics Surveys	• Evidence of user perceptions and experiences of usability and learnability towards training formats, GFD systems, and training experience • Limited descriptive profile data
Flight Debriefs – Informal Interview	• Clarification, corroboration, and expansion on evidence from field notes and observations

Note: The data collections strategies used for the study, with examples of the kinds of case evidence that were collected as a direct result of the applied strategy.

Data Sources - Research Questions and the Data Collection Strategies

The selection of the data collection strategies should be chosen such that the data acquired will optimally address the research questions. The data collection strategies were specifically selected for their recognized benefits in executing this research study. Each data collection strategy was particularly selected for its intrinsic values in performing qualitative research and for its potential contribution in acquiring data that will help to specifically answer each of the research study questions posed. Taken collectively, the researcher found all of the data collection strategies to contribute holistically to the goal of answering the research questions. However, each data collection strategy also offered unique benefits to directly inform the researcher in answering the individual research questions. The research questions are matched the with the selected data collections strategies in Table 2.

Table 2

Research Questions - Data Collection Strategies

Research Question	Data Collection Strategy(s)
1. To what extent does the quality of user learning and training experiences improve by utilizing a scenario-based training approach to the use of glass flight deck systems by pilots?	• Experiential Survey • Flight Debriefs – Informal Interview • Observations
2. To what extent does the quality of the learnability and usability experience of pilots utilizing a scenario-based training approach improve their satisfaction with, and perceptions and attitudes of their use of and reliance on glass flight deck systems?	• Flight Debriefs – Informal Interview • Observations • Usability/Learnability Survey
3. What, if any, are additional instructional design improvements in glass flight deck training suggested or found through implementing the changes in the training methodology as proposed?	• Flight Debriefs – Informal Interview • Observations • Usability/Learnability/Experiential Surveys

Note: For each research question, there is (are) one or more data collection strategies yielding study data that helped to answer the research questions posed

Researcher Observation

Observations are a key component in understanding real-world in-context situations and events (Marshall & Rossman, 2011; Yin, 2014). Observations were used to acquire valuable case evidence in pursuit of the researcher's aim to better understand pilot perceptions and attitudes towards GA glass flight deck systems during pilot training activities on GFD systems. The researcher incorporated two types of observation strategies – casual field notes and structured training observations. Observation techniques were used throughout the completion of legacy classroom instruction, computer-based training systems (CBTs), and flight training devices (FTDs). The researcher recorded a mix of casual and structured observations throughout the training process. These observations served to provide the researcher's point of view of the participants' learning experiences and training progress.

The researcher utilized casual (or informal) observations and catalogued the observations as field notes. Casual observations are researcher-documented observations that are second hand accounts of a situation or event. The researcher collected and recorded field notes for all phases of training while the teaching faculty managed the training process. For example, before a training session started or during breaks in a training session, the researcher documented participants comments, behavior, the training environment setting, group discussions, etc. While teaching faculty were busy moderating the training process, the researcher made note of observations. These information "nuggets" were recorded in simple handwritten field notes in a journal and subsequently transcribed. These nuggets of information aided in the development of researcher impressions, ideas, or hunches about the training environment and ongoing learning process. The information also served to point out and generate additional clarification questions desirable for the flight debriefs.

An observation protocol form was used to monitor the individual training phases. Special emphasis was placed on using observations during all hands-on flight tasks of the SBT training activities. Training phase observations were very similar to observations made of participants in usability evaluations while they were executing usability task list. The primary difference was that training phase observations were done using a pre-established protocol and were most often used while observing more than one participant at the same time. For example, during the hands-on flight tasks training activities, the researcher recorded the ongoing dialogue between faculty and participants and took notes pertaining to their use of training resources (materials, equipment, software programs, etc.), and the physical setting. The researcher recorded details of the participants ("thinking aloud" comments or utterances, between-participant dialog, behavior, actions, questions, etc.) along with reflective and descriptive notes of their experiences and interaction with the computer-based and simulated flight equipment used during training.

Both types of observation documentation provided the opportunity to collect valuable and useful qualitative information. All observational data were kept for subsequent analysis by the researcher for reflective and ethnographic purposes, and as an aid in developing the researcher's insight of the overall training process. Some of the data collected were analyzed with a qualitative software program (NVivo) useful for building a visual map of themes and codes. Further discussion of this process is addressed in Chapter 4. Field notes and training observations were expected to a.) serve to supplement triangulation with other data collection efforts, b.) aid in the development of themes and codes c.) provide for additional inquiry during face-to-face or flight debriefs interviewing, and d.) lead to additional researcher insight. Examples of the recording documents used for field notes and formal observations are provided in Appendix D.

Instrumentation

Questionnaire Instrumentation

In addition to the observation documents above, three instruments were used. At the start of the training process, a questionnaire was used to collect pilot profile and demographic information. A survey instrument (used twice – see Appendix E) captured the participants attitudes towards GFD systems – one prior to starting the training regimen, and one following completion of the entire training process. This survey instrument presented a series of five statements to the participants with a Likert scale, which the participants used to rank their agreement/disagreement with each statement. A second survey instrument assessed the participants' learning experiences with both the CBT GFD and FTD GFD training systems. This survey instrument was a modified Systems Usability Survey (SUS), originally developed by John Brooke (1996) and used extensively in testing user interfaces by many researchers over the past several decades. The SUS provided a measure of the usability attributes of learnability and user satisfaction, and created an opportunity for the researcher to compared participants' perspectives on the usability of both of the training systems. As with observation documents, all questionnaire and survey instruments were maintained and stored in digital formats for easy review, retrieval, and analysis.

All instruments were be handled electronically online using the Internet-based service, Qualtrics. Qualtrics is a professional grade online survey creation and distribution service recognized as one of the top survey tools service providers in higher education markets. The researcher's university employer has contracted Qualtrics services on behalf of all institutional employees to be used for all academic research and endeavors on campus. David Carr (2013) described Qualtrics as "the dominant" academic research survey provider. Qualtrics' CEO, Ryan Smith, touts being the primary survey services provider for 1300 colleges and universities worldwide, primary provider to 95 of the 100 top business schools in the United States, and the primary business partner to fifty-percent of the top corporations in America (Carr, 2013; Smith, 2014). See www.qualtrics.com/ for additional information.

The pilot demographics and profile questionnaire collected basic demographic and experience profile information from the participants. The pilot profile questionnaire was a modified instrument based on standard demographics-oriented surveys, combined with pilot-oriented demographic and profile-type questions specifically created by the researcher. Participants checked boxes (data ranges) for a variety of profile information including general demographics (e.g. age, gender, academic status, etc.) pilot demographics (e.g. current certifications, endorsements, ratings, etc.), and pilot experience (e.g. types of aircraft flown, hours of flight time logged, extent of flight experience with advanced avionics, etc.).

Survey Instrumentation

A modified survey instrument - the GFD survey, based on the System Usability Scale (SUS), assessed participant learnability and usability experiences with the training resources following the completion of each training phase. The original SUS was created by John Brooke in 1996 and is recognized as an industry standard as a measuring instrument when administering usability tests. It is widely used and is a component of commercially available usability evaluation toolkits. Brooke's original SUS instrument has been modified, consistent with traditional research application and use, replacing the word "system" with "glass flight deck (GFD) system", and no changes were made to the *Likert-type* rating scale. Consistent modifications in this manner are recognized as acceptable with the SUS survey use, and noted by Lewis and Sauro (2009) as having no effect on resulting participant scores, reliability, or validity.

The training phase GFD SUS surveys were administered using the Internet-based online service Qualtrics. Participants accessed all surveys anonymously. Participants were asked to answer a series of statements focused on eliciting their attitudes towards glass flight deck systems, their perceptions regarding the use of glass flight deck systems, and their overall training experience.

The survey was presented in a statement-based format, allowing the participants a range of agreement responses to each statement using *Likert-type* scales of strongly disagree/strongly agree. For example, participants were asked to rate their agreement with a specific statement relating to the usability of a specific training task or piece of equipment with regard to their ability to apply what they learned. The statement might read, "I found the various functions in the GFD system were well integrated", and the participant indicated how strongly they agreed or disagreed with the statement.

A single "additional comments" follow up question gave participants the opportunity to provide any additional details they might want to share. The option to offer additional comments provided an opportunity for participants to expand on their training experience, the usability of the training resources, and any other feedback they may choose to provide. Training phase SUS survey data helped in triangulating and validating observational data. This survey data also provided connections to the coding and thematic phases in the data organization, analysis, and interpretation stages of the study.

Flight Debriefs – Informal Interviews

The researcher used one of the more common qualitative interview formats. An essential source for evidence about human actions, interviews are one of the most important types of data that a researcher can collect. The researcher used two flight debriefs in this study - in-person informal interviews completed in a group setting. Flight debriefs consisted of discussions with all the participants following completion of both of the GFD systems training sessions. Flight debriefs were used to expand on participant training experiences and clarify the researcher's observations.

The flight debrief interview format provided specific advantages for data collection. The flight debriefs were conversational and informal in nature, allowing the researcher to ask open-ended questions. The flight debriefs lasted from 30 to 45 minutes. The objective of the flight debriefs was to elicit participants' views and perceptions about the scenario-based training process.

The flight debriefs focused on the case study approach to using scenario-based training and the impact on the pilots' usability and learnability experience, as well as their satisfaction with the overall training. For example, the researcher asked, "Let's discuss your experience with how the training scenarios affected your ability in learning to use and master the training materials and equipment." Additional questions were used to draw out participants' responses even further. Another example question was “Describe whether or not these training scenarios make you feel like you can effectively apply these skills in the real aircraft while in flight.” from Participant responses were recorded on paper using the flight debrief protocol form. The protocol form acted a guide for the researcher, and included notes to remember along with the open-ended questions that were asked.

The researcher used the flight debrief protocol form to manage the debrief process and insure consistency with both of the group debriefings. By using open-ended questions, the researcher had the opportunity to probe and to delve deeper into the participant’s perceptions, experiences, and attitudes, and gain additional insight through participant explanations. Data collected via the flight debriefings were used to triangulate the evidence acquired via the online surveys, observations, and field notes. An example of the flight debrief protocol form is provided in the Appendix D.

Table 3 summarizes each session and training phase along with its respective data collection strategy(ies) used. The training format for each phase is identified, as is the use of observation, survey, and/or interview as the individual strategies used to collect study data. (See Figure 3 - previously presented – for a visual depiction of the training phases and the data collection strategies.)

Table 3

Training Phases / Formats - Data Collection Strategies

Training Phase / Format	Data Collection Strategy
Orientation Session / General Discussion (est. 1.5 hr:2x.5 & 1-10min break)	• Overview of study objective and goals • Sample CBT/SBT exercises and flight • Questionnaire – Pilot Demographics • GFD System Attitudinal Survey
Phase #1 / Traditional Classroom Lecture/Presentations / Computer-based Training (CBT) Mix (est. 3 hrs:2x1.25 & 2-15min breaks)	• Observations of training environment • SUS Survey – Learnability and User Experience • CBT/SBT Group Flight Debrief
Phase #2 / Scenario-based Training (SBT) - Discreet Flight Tasks and Complete Flight Plan on Flight Training Device (FTD) (est. 4 hrs:1x1.5, 1x2 & 2-15 min breaks)	• Observation of activities of completing discreet flight tasks and FTD flight • SUS Survey – Learnability and User Experience • FTD SBT Group Flight Debrief
Post-training Session / (est. 1 hr: 2x.5 - no break)	• Review of Study • Final Training Debrief • GFD System Attitudinal Questionnaire

Note: For each phase of training, specific data collection strategy(s) were used to collect case evidence, with each phase's strategy(s) eliciting multiple types of evidence used during analysis.

The use of observations, surveys, and group interviews were significant and key qualitative components of the evidence for this case study research. It is through the triangulation of the various data components that the researcher was able to improve the overall credibility and trustworthiness of the study.

Evidence Organization and Storage

Good organization and storage strategies are recognized as sound methods for working with case evidence. The researcher recorded all observations on paper and cataloged each document. Questionnaire and survey data were also catalogued, and stored electronically in their original online survey format. All evidence that could be tied directly to a specific participant is stored by their pilot call sign – their privately coded substitute identity.

The researcher organized and documented the case evidence collected for easy review and access. Evidence was converted into manageable, appropriate text units that were then analyzed manually and by computer software programs. Common business applications of Microsoft Office Word and Excel (.docx and .xlsx file types) and Adobe Acrobat (.pdf file type) were used to digitize all case study evidence. For example, the researcher transcribed, scanned, and transferred all observation documents into electronic formats (.pdf, .rtf, .docx, etc.) for subsequent analysis on a computer. A software program designed for storing, managing, and analyzing qualitative data types was used (QSR's NVivo program). The software was also used to confirm and develop coding and thematic analysis of the data.

Data Analysis

Transcription / Digital Conversion

Transcription and digital conversion was completed for all recorded information captured during the collection of case evidence. As the evidence collected was already de-identified via the use of pilot call signs, no identity or privacy concerns accompany the digital conversion and transcription processes. The researcher did not utilize any audio or videotaping in the process of collecting case evidence.

All researcher observations and group flight debriefing discussions were hand written and required some transcription prior to conversion to digital formats. For example, all handwritten notes and information captured on observation protocol forms were transcribed and scanned before being converted to a digital document (e.g. Adobe .pdf and MSWord .docx). All digitally converted documents were cataloged by name, date, time, and stage of study. A more in-depth discussion regarding the process of cataloging all evidence is addressed in the section Evidence Organization and Storage.

Many of the handwritten notes were transcribed by using dictation software to convert field notes to a digital format. A software program (e.g. Acrobat, NVivo, etc.) capable of scanning for optical character recognition (OCR) was used to the convert the digitally transcribed and scanned handwritten information into readable text. The researcher scrutinized each digital and scanned document to insure there was an exact match to the handwritten documents, making any corrections by manually typing/editing the digital files. Upon completion of digital conversion and transcription of all observational and interview evidence, all digital documents were processed for additional analysis and manipulation with NVivo software. The NVivo software assisted the research in analyzing the digitized data, taking counts of key words and phrases, and developing and building useful visual maps of codes and themes.

Qualitative Analysis

The researcher adopted a subset of Huberman and Miles' (1994) systematic approach to analyzing case study evidence. Application of this data analysis strategy involves several sub-strategies including sketching ideas, taking and summarizing field notes, working with words to create codes and themes, counting code frequencies, developing categorical relationships, and the display and presentation of data. The researcher used a combination of manual and digital techniques, and followed a systematic approach to data analysis. Adapted from Huberman and Miles (1994) work as presented in Stake's (1995) seminal work "The Art of Case Study Research", Table 4 summarizes these analysis strategies employed in this study.

Table 4

Case Study Evidence Analytic Strategies

Analytic Strategy	Action or Procedure
Note-taking / Idea Sketching and Summarizing (observations and field) notes	• Write margin notes/reflective passages (on observations) • Draft a summary sheet on (observation and) field notes
Code labeling and frequency counting	• Identify labels/codes for common words/phrases • Count frequency of codes
Code reduction to themes/ideas	• Note patterns and themes • Merge similar patterns/themes into abstract ideas
Displaying the data	• Make contrasts and comparisons

Note: Adapted from discussions within "The Art of Case Study Research," by R.E. Stake, 1995. Copyright 1995 by Sage Publications, Inc.

Data analysis involved an ongoing process of the following three core steps: a) careful in-depth read-throughs searching for common data segments for labeling and categorization (i.e. coded) as similar or related, b.) repeated review for similar categories (codes) that could be condensed and aggregated into themes while looking for broader abstract ideas, and c.) finding ways to visually represent themes to facilitate interpretations to be made. It is important to note that this process was not linear. Rather, the researcher repeatedly used manual and digital analyses in executing these analytical steps – more than once – multiple times reading over the data collected seeking for codes, aggregating codes into themes and broader ideas, and developing ways to present the broader ideas. Figure 4 is a graphical representation of the circular process of these three core steps that were used to analyze the data.

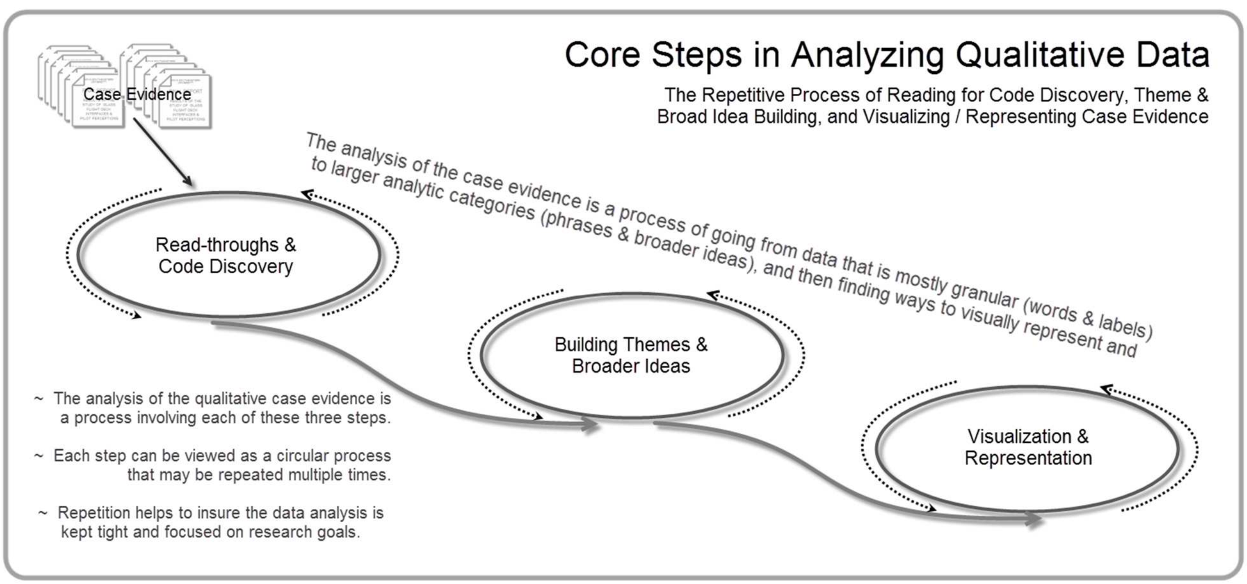

Figure 4. Core Steps in Analyzing Qualitative Data: The repetitive process of reading and code discovery, theme and broad idea building, and visualizing and representing case evidence.

There were a number of strategies to keep the focus of the data analysis tight and directed at addressing the research questions. The researcher took an inductive approach to building a set of codes and themes with the help of the NVivo program. In applying the first core element, while the in-depth review of the evidence was being done, words, phrases, and small segments of information were manually assigned labels – which are generally referred to as *codes* (the process is known as *coding)*. The codes were a mix of labels identified from the process of developing the case study research goals and questions and the scholarly articles reviewed as part of the comprehensive literature review process, with some codes emerging from participant words/phrases captured during the observations and interviewing processes.

Special attention was given to the thorough reading of the evidence, and through a vetting of the codes discovered by applying 'categorical aggregation' and 'working the data from the ground up' strategies. Categorical aggregation places an emphasis on developing both qualitative data (pulling the data apart and putting it back into meaningful first impressions) along with quantitative data (frequency counts of evidence instances) (Stake, 1995). Working the data from the ground up emphasizes the discovery of paths or concepts through a process of playing with the data, to reveal possible codes (Yin, 2014).

The researcher then organized codes by their similar aspects and characteristics and group them as broad units of information that reflect common ideas. These broad units of information are known as *themes.* Specific techniques were used to delve as deep as possible into the process of discovering themes. Scrutinizing similarities of like-patterns was used to aggregate coded information to the broader theme development. Searching for pattern consistency and matches in patterns resulted in a more accurate development of themes – known as *pattern searching* (Stake, 1995, pp. 78) or *pattern matching* (Yin, 2014, pp. 143). The use of these processes enabled the researcher to develop a deeper understanding of the evidence and ultimately aided in a more stable and grounded interpretation process.

Themes were organized into larger abstract information units aimed at making a more abstract sense of the evidence. The objective was to develop a deeper understanding of the evidence in an attempt to make sense the larger abstract units of information. Ways of representing the data were developed (e.g. word clouds, graphs, charts, tabular comparisons, hierarchical structures, etc.) aimed at presenting visual representations that were used to further aid the researcher in understanding of the evidence collected. The researcher found that interpreting the evidence in this way helped to better understand the ‘lessons learned’ from the study.

As noted in the Evidence Organization and Storage section, managing the overall case study evidence library was accomplished with a popular software program (NVivo) used in qualitative research studies and case study evidence management. This type of program assisted the researcher in manual efforts to organize and index a stored library of evidence, to document, manage, access, and compile codes, and in developing conceptual mapping of the data. The program offers tools that helped the researcher to build visual maps of code relationships and thematic models, and aided in helping the researcher to conceptualize different levels of abstraction in the evidence collected.

Statistical Analysis

Limited statistical analysis and presentation were planned for the data captured in this study as much of the data were qualitative in nature. However, there were appropriate places where limited descriptive statistical analyses were applied. This includes the data acquired from the pilot demographic/ profile survey, the participants' SUS surveys, and time and date stamp data collected during the SBT FTD flight scenarios.

For example, distributions of participants' age, academic status, and ratings were plotted on an Excel spreadsheet. Ranking the number of total flight hours compared to hours of glass flight deck experience was quite informative. Various charts showing comparisons of pilot profile data, academic status, number of certificates and rating held, etc. offered additional insight the researcher found useful in triangulating much of the qualitative (observational and interview) data.

Additional descriptive statistics were clearly found to be of value when reviewing and measuring participant responses to SUS learnability and user experience and satisfaction statements. Simple means and reliability calculations helped the researcher in developing an overall insight of the participants' perceptions and attitudes towards GFD training systems. The use of quantitative representations offered additional insight regarding the overall group of pilots participating, the relationships between the various evidence collected, and the ability to identify any changes in participant perceptions overtime.

Data Presentation

Presentation of the data analyzed takes one of several forms based on the appropriate type of visual display for the data presented. Use of textual narratives, tabular formats, and graphical figures are used to visually supplement the extensive in-depth discussion of the results of the study and the case study evidence. Descriptive statistics tables are used to communicate percentage figure results obtained from the pilot responses to questions from the various interview surveys. Comparison tables are used to show the relationships between various data sets, both qualitative and quantitative data types. Hierarchical tree or organization trees are used to present coding data and categorical aggregations, patterns, and themes.

Narratives are used to provide a detailed description of the case setting, the study environment, and participants' behavior, comments, and actions during the study. Narratives are also used to convey the chronology of training events as they occurred, and also serve as summaries or short statements of the overarching perceptions and attitudes of participant responses to flight debriefings, the GFD SUS surveys, and the final training debrief.

Reliability and Validity

Qualitative studies offer a number of reliability and validity strengths, however reliability and validity do not carry the same exact meanings or labels as in quantitative studies. In qualitative studies, reliability is often further defined by such words as dependability, replicability, and consistency, while validity is often replaced with labels of credibility, accuracy, trustworthiness, and authenticity (Creswell, 2013; Marshall & Rossman, 2011; Stake, 2006). A number of strategies exist for improving reliability in qualitative case studies and involve having extensive documentation procedures, rich contextual and field documentation, and researcher peer reviews and cross-checking. A number of strategies also exist to improve validity in qualitative case studies. Appropriate strategies include the triangulation of data, the use of member-checking, having extended field experiences, clarification of researcher biases, presentation of negative and contradictory information, peer debriefing, and the use of external auditors (Creswell, 2013; Marshall & Rossman, 2011; Stake, 2006; Yin, 2014).

The researcher focused on several of these strategies to improve reliability and validity. For example, the consistency and accuracy of codes and development and abstraction to themes were improved by the use faculty peers in cross-checking the process throughout. The participating faculty and staff CFIs were routinely and frequently consulted with regard to the researcher's interpretation of qualitative data collected from observations and flight debriefs. Error checking techniques were also used to establish consistency in participant survey responses.

Similarly, several strategies were employed to improve the validity if the study. Included were the use of controls of the evidence, and the triangulation of the data. The participants were engaged in member-checking activities, and faculty participating in the study were engaged for peer reviews of evidence collected during direct observations and personal interviews. The evidence collection, analysis, and storage process was extensively documented using strict protocols, and all coding and theme development of evidence was catalogued using the SQL database-oriented NVivo computer software program. All data captured are available for access by readers and for review at any time up to three years following study publishing. Complete disclosure of researcher biases have also been made to clearly inform the reader of areas where researcher bias may exist.

Survey Validation

The use of Brooke's System Usability Survey (SUS) has a long history for assessing usability constructs such as learnability, user experience, and user satisfaction (Brooke, 1996). The survey's ability to accurately measure perceived usability is regarded as high among the research community. According to Sauro (2011), the SUS survey has been shown to "discriminate, as well as or better than proprietary questionnaires, between systems which have poor usability and those that are considered usable" (pp. 91).

Research instrument reliability ranges zero to one with one being perfect reliability. Survey instrument reliability relates to a survey's consistency of measurement. Sauro and Lewis (2012) reported recent reliability assessments (2008-2010) using varied sample sizes, and having found the overall reliability of the SUS survey to have a coefficient alpha (Cronbach's alpha) of just over 0.90 – well over the 0.70 coefficient regarded as acceptable. Additionally, the SUS survey has received high concurrent validity marks. A survey's validity is the extent to which it measures what it is intended or claimed to measure; validity measures of over 0.50 are considered quite acceptable. Brooke's SUS survey has been shown to correlate highly with other established questionnaires used for measuring usability and learnability. Reflecting typical Pearson correlation coefficient scoring for validity, Sauro and Lewis (2012) reported validity measures of over 0.80 for the SUS survey for the same assessment date ranges used for evidence of reliability. The use of simple but verifiable quantitative statistics (correlation coefficients) were used to insure reliability in the participant usability surveys collected. The researcher modified the SUS survey to more appropriately reflect the specific GFD system being assessed in this study. This type of modification is a widely recognized and accepted process for adapting the original SUS survey, without influencing or diluting the instrument's original reliability or validity.

Data Analysis and Triangulation

Additional controls were used to maintain the chain of multiple sources of evidence collected, and improve the validity of the evidentiary relationships. The use of multiple sources of data for purposes of corroboration is well known as data triangulation, and corroboration through increased data triangulation should increase the confidence in the observations made, and the results achieved (Lazar, Feng, and Hochheiser, 2010; Yin, 2009). Schwandt (2007) proffered that only by the use of data triangulation can the integrity of researcher's inferences and conclusion drawn from the multiple sources of evidence be checked and affirmed. It is through the use of converging lines of inquiry, that reliability of the study data is increased. Adapting discussion from Lazar, Feng, & Hochheiser (2010), Yin (2014), and Schwandt (2007), the process of converging multiple and different forms of case evidence on case study findings can be graphically depicted as shown in Figure 5.

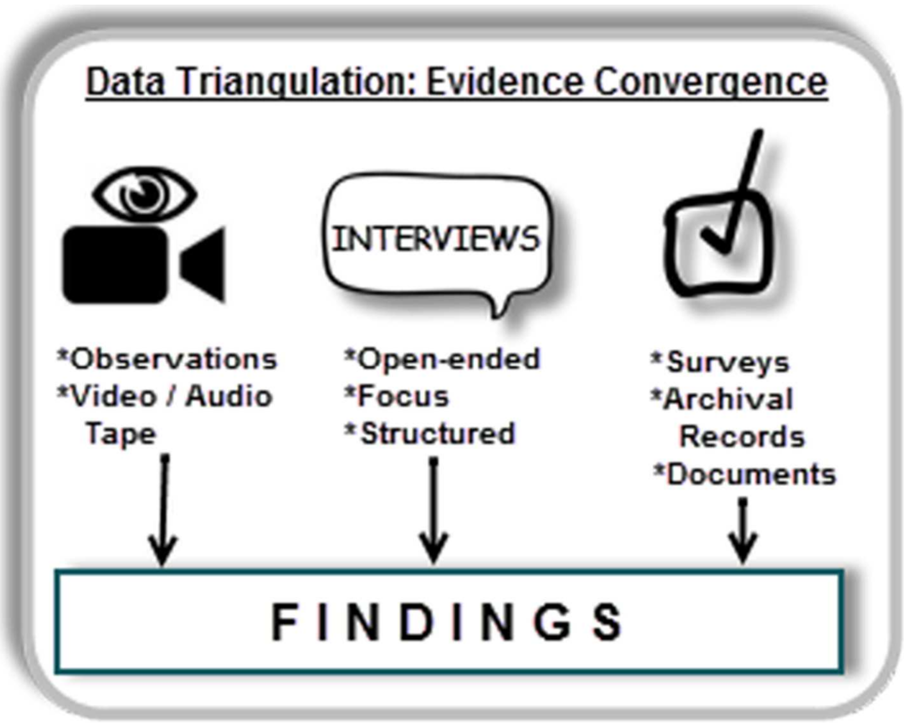

Figure 5. Data Triangulation: The Convergence of Evidence on Case Study Findings. The convergence of multiple sources of case study evidence for purposes of corroboration is known as data triangulation. Increased data triangulation generally increases the confidence in the study findings and ultimately the results reported.

Stake (2006) and Schwandt (2007) noted that multiple evidence sources converge, or aggregate, to reveal the *real* truth of the phenomenon under study. When developing convergent evidence through data triangulation, construct validity is said to increase. Stake (2006) wrote that, as form of validation, the use of data corroboration through triangulation “assures that we have the picture as clear and suitably meaningful as we can get it, relatively free of our own biases, and not likely to mislead the reader greatly” (p. 77). Through data triangulation, the findings and conclusions of the study are apt to be more accurate and convincing. The use of procedures for cataloging the evidence collected, data triangulation strategies, and storage of evidence in a well-organized database will serve to improve the reliability and validity of the evidence collected. These are strategies that Creswell (2014) and Schram (2006) emphasized are important to apply as the credibility and reliability of the findings, and that of the overall trustworthiness of the study, is substantially increased.

Member Checking and Peer Review

At select points in the training regimen, pilot participants were engaged to review and provide feedback on the initial summaries and themes developed by the researcher throughout the data collection and analysis processes. The goal was to gain more objectivity, accuracy, and neutrality of representation of their training experiences. Participants were given the opportunity to react to and judge the accuracy of the researcher’s representations of the training environment so that they could correct any misinterpretations, as well as clarify or add any additional insights. This process, known as *member checking,* has been identified as “the most critical technique for establishing credibility” (Creswell, 2013, p. 252).

The tenured faculty and staff delivering the training were also engaged in member checking and peer review activities throughout the study. The faculty and staff provided reactions and feedback with regard to the researcher's interpretations of the data collected from direct observations and interviews. They also had various opportunities to review case summaries, coding and themes developed, and analytical notes and report drafts with the objectives of providing corrections and additional insight. Member checking and peer reviews improved the accuracy of the case presentation, and increased validity of the case study results.

Researcher Roles, Ethics, and Bias

The researcher took various roles (e.g. teacher, advocate, evaluator, biographer, and interpreter) in the course of the case study. In the context of this case, the researcher's roles changed often during the study. For all roles the researcher took, the highest of ethical standards were maintained. Ethics dictate that a full disclosure be made of the researcher's personal and professional experiences, background, and any relationships to the study. Researcher biases with regard to potential impact on philosophy underpinning the study design and the reporting of study results are discussed and addressed below.

Researcher, Evaluator, and Interpreter

The researcher assumed no teaching or instruction responsibilities during the training regimen, but did participate in instructional design of the learning materials, content, flight training scenarios, and the coordination of training events. All training components (i.e. phased instruction, coursework tasks, performance assessments, etc.) were delivered and managed by tenured faculty and staff at the Midwestern aviation university. The same faculty and staff delivering the training also conducted member checks and peer review activities. Member checking and peer reviews improved the accuracy of the case presentation, and increased validity of the case study results.

One of the researcher's primary roles was to arrange and provision the information to inform and increase competence for the reader and to introduce familiarity of the case study terminology and expose similar experiences for the benefit of the reader of the study. The researcher also assumed the primary roles as an evaluator and interpreter. Acting as an evaluator, the researcher gave careful attention to the merits and shortcomings in evaluating and making interpretations of the case evidence. As an interpreter, the researcher worked with dedication to recognize case issues, study them at length and make new interpretations and meanings. This process was used to help the reader comprehend new meanings towards new knowledge and to substantiate that knowledge for the reader.

The researcher's primary roles were reinforced by the desirable skills of being a good questioner and good listener. Assuming the role of being a good questioner throughout the study, the researcher was watchful for the potential need of new or probing evidence and for asking additional questions. Similar to being a good questioner, the role of being a good listener was equally important. The researcher strived to be open to receiving information via multiple modalities (ears, facial expressions, posture, etc.) while being careful not to color the information received with the researcher's own perspectives, and to avoid listening with a closed mind. Concerted effort was made toward hearing the exact words of the participants, looking for cues when to "read between the lines" for messages and inferences not spoken or written. These roles as good questioner/good listener complemented staying adaptable in the overarching role of researcher, being able to change procedures and plans when unanticipated situations or events occur, and yet still be able to maintain an unbiased perspective when change is required.

Researcher Ethics

Being an ethical researcher is of the highest importance, and the researcher of case studies must constantly strive for the highest ethical standards. Maintaining participant privacy and anonymity will be a priority observed throughout the execution of the study. The researcher has committed to complete the confidentiality, privacy, and anonymity of all participants and their personal information. Participant identities have been well protected and maintained by the use of pilot call signs chosen by the participants themselves.

Careful evidence storage strategies were followed to insure all participant data was protected and securely stored. The researcher restricted access and exposure of pilots' participation and activities to only those faculty and staff members engaged in the study. Additionally, maintaining high ethical standards helped in avoiding potential biases of predisposed orientations, or the advocating of findings in one direction or another. High ethical standards also helped to maintain the tolerance necessary for working with any contrary findings that arose. Holding to a high standard of ethics also aided in maintaining scholarship throughout the study, avoiding deception and fraud, and maintaining accurate evidence representation – all of which improves overall reliability and credibility of the case study.

Researcher Bias

Full statements of disclosure are made so the reader of the study is fully informed and can weigh and determine the results of the study for oneself. The researcher explicitly discloses below any personal, professional, work, or education background information, any relationship to the case study setting or participants. Also disclosed are any past experiences with the case study problems studied that may shape the researcher's interpretations or be biases that may lean the researcher toward certain themes or positions of philosophy regarding the study results.

As the fourteen year manager of a professional multimillion dollar flight instructor and pilot training facility at the Midwestern aviation university, the researcher has been working to improve the simulation and training environment so that pilots receiving training have the most current hardware and software training platforms on which to learn. From this professional position, the past half-decade has been spent specifically on upgrading and implementing new training devices and computer-based systems for the training on GFD systems for hundreds of flight instructor and pilot students. Within this recent timeframe, the researcher has also been involved collaboratively with current departmental faculty in efforts create, change, and improve the curriculum and training content used for learning and training on the use of GA glass flight deck systems. The efforts in this professional setting over this timeframe have affected the flight instructor-oriented assumptions and perspectives that the researcher brings to the study.

Perspectives and experiences of training with glass flight deck technology exist as the researcher holds a pilot license and has received pilot training over a period of years that include instruction on the use of glass flight deck technology in general aviation aircraft. The researcher also owns a small GA airplane typical of the training aircraft found on instruction flight lines at many airfields across the country. The researcher's aircraft currently includes avionics that are considered subsystems of a GFD system for which pilot training has been completed. The researcher's training and learning experiences on the use of the typical GA aircraft over the past decade includes training on the use of glass flight deck subsystems. Therefore, the researcher also brings personal, pilot–oriented assumptions and perspectives to the study based on these past instructional experiences.

Procedures

A primary aim of this study was to better understand pilot perceptions and attitudes towards GA glass flight deck systems throughout the duration of the training activities with GFD systems. The researcher proposed to specifically adapt the current GA glass flight deck training methods though incorporating the use of a combination of legacy classroom instruction, computer-based training systems (CBTs), and flight simulation in GA aircraft flight training devices (FTDs). Scenario-based training was incorporated at select steps in the training regimen in pursuit of investigating the goals of this study, and in addressing the reported problems with current training methods and techniques. The training took place during a traditional 16-week undergraduate university semester.

Training was completed in phases. Each training phase was a mix of a traditional lecture/presentation of learning content, several scenario-based tasks and exercises, and hands-on training with the GFD systems. Stepping through a training phase, the process involved the presentation of the learning materials and content to be mastered in a traditional CBT classroom format. This was intertwined with guided and self-paced applications of the learning content in a scenario-based set of tasks on a CBT system. Each training phase was completed by a final scenario-based set of exercises or tasks intended to master the learning content and GFD system components. A timeline of each of the training phases is outlined below.

Training Phases

This study involved the incorporation of a pre-training orientation session, two phases for glass flight deck training, and a post-training closing session to address the goals of this study. The pre- and post- sessions and two training phases took place over the course of two full training days, with an additional day planned as buffer time to accommodate issues with participant schedules, equipment concerns, and any unforeseen events. The additional buffer time was not needed. Training time was kept fluid and each training session lasted about three and a half to four hours. Table 5 provides an outline of the phases and training formats followed along with timeline and duration estimates for each phase.

Table 5

Training Phases: Summary Timeline

Phase Number and Type	Duration and Timeline
Pre-Orientation Session: • Overview of Training Phases and Types of Data Collection • Completion of Pilot Profile & Attitudinal Questionnaire	• Approximately one hour and 30 minutes in length • Occurs: First day of training regimen
Phase #1: • Traditional Classroom Format • Lecture/PowerPoint/Textbook and OEM Manuals • Computer-based Training (CBT) Format • Guided Discussion and Self-paced Lessons	• Training Session: Approximately three hours in length. • Occurs: First day of training regimen

Table 5 Continued

Phase Number and Type	Duration and Timeline
Phase #2: • Scenario-based Training (SBT) Format • Guided Flight Tasks in FAA-certified Flight Training Devices (FTDs) • Entire Flight Plan in FAA-certified Flight Training Devices (FTDs)	• Training Session: Approximately four hours in length. • Occurs: Second day of training regimen
Post-training Session: • General Discussion, Flight Debrief, Study Review	• Approximately one hour in length • Occurs: Second day of training regimen

Note: Actual training timeline for each training phase and type of training involved, when occurring during training regimen, and the estimated length of each training session.

Pre-training Orientation Session

The participants took part in a pre-training orientation session prior to entering the first phase of their training. The pre-training orientation included a review of the study’s aim and two training phases were presented. Discussion took place describing and explaining the training phases and the manner in which data was to be collected. Participants had the opportunity to ask questions and express concerns. The pre-training orientation session closed with participants completing the pilot profile and attitudinal questionnaire. The pilot profile questionnaire covers general topics of pilot-specific demographics and pilot flight and training experience. It also assessed the pilot participants’ current perceptions and attitudes towards GA glass flight deck systems.

The two training phases involved a combination of the traditional classroom instruction currently used to train pilots on GA glass flight decks, supplemented with computer-based training (CBT) programs simulating the operation of GA glass flight decks. Training concluded with the use of actual aircraft flight training simulation devices (FTDs) equipped with GA glass flight deck systems, and entire flight plans were completed in the FTDs. Both phases of training had predefined flight tasks and flight segments wherein the researcher observed the pilots actions (behavior, attitudes, comments, etc.) while completing the training content and exercises. The researcher recorded notes using the observation forms previous discussed. Following completion of each of the two training phases, participants completed the GFD survey (learnability and user experience). Observation recording forms and the GDF survey can be found in the appendices.

Phase I

Following the pre-training orientation session, the participant pilots began training on GA glass flight deck systems with traditional classroom instructional materials. These included the traditional textbook and general orientation lectures to GFD systems, the various components and their functional use, manufacturer and training operational systems manuals, and video demonstrations of the use of GFD systems in the real flight environment. A faculty member took participants through a typical lecture set of learning content on a specific glass flight deck training tasks. The researcher was present for all CBT flight task exercises, and observed the participants' training experience. Observations of the each of the CBT training operations were recorded on field notes observation protocol form.

After the traditional classroom instruction, an orientation to the CBT GFD system was presented, and followed with limited hands-on exercises presented. Participants were immersed and engaged using CBT laboratory environment where they had guided instruction on the use of GA glass flight deck simulated computer software to apply the knowledge learned during the traditional lecture format. Utilizing the mouse and keyboard, the participants were able to objectively manipulate the basic glass flight deck components (buttons, switches, menus, subprograms, etc.) to achieve basic operational functions required for the training tasks identified in the first phase. Limited scenario-based training (SBT) tasks were introduced to aid in learning and practicing with the various GFD subsystems on the CBT systems.

At the end of the first training phase, the participant pilots were capable of identifying the task required glass flight deck components covered, could explain their use and application, and provided a generalized understanding of the GA glass flight deck subsystems interrelationships. (Traditional coursework knowledge exams typically given to the pilots receiving this type of training would be completed at this point. This study did not include any coursework exams and no coursework assessment data such as this was captured.)

Phase II

Subsequent to the CBT exercises, the second phase of training introduced more rigorous scenario-based training (SBT) activities via an advanced SBT flight scenario to the participant. While completing the first phase of training, the participants practiced using the GA glass flight deck systems in small piecemeal flight tasks. In the second phase, the participants completed a series of robust SBT activities indicative of a formal flight plan involving coordinated flight operations and maneuvers. Participants were issued a series of specific flight plan segments recognized as common flight plan operations. These in FAA-certified flight simulation training devices (FTDs) used in the Midwestern aviation university flight training laboratories.

The researcher was again present for all SBT flights, and observed of each of the participants' SBT flight experiences. Observations of the each of the SBT flight operations were recorded on field notes observation protocol form. Additionally, the CFIs recorded brief notes and time stamps for each participant as they flew the SBT flight scenario. The data recorded for each flight plan as it was being flown, was originally intended to help keep each participant on track during the flights, and to insure the CFIs stayed engaged and in control of the execution of the flight plan as it moved forward.

The researcher utilized these time stamps and notes to further analyze the participants' flight experiences. Limited descriptive statistics were calculated and analyzed in relation the context of the SBT flights observation recordings made. This data also served to supplement the researcher' recorded observations, helped in triangulation of the SBT flight experience data, and was useful in member checking efforts with both the CFIs and the participants. The participants' took a final GFD survey (learnability and user satisfaction) to assess their perceptions of the training on the GFD system. (See appendices for the form and survey used.) Following the second training phase, a post training session was held as the final step concluding the training regimen.

Post-training Session

Following completion of the second training phase, a final training interview was completed with all participants using a format similar to the Flight Training Debrief Protocol. The final training debrief concentrated on questions and discussion of the SBT training format, the use of scenarios to learn and master glass flight deck systems, and the impact of scenarios on the entire training regimen. The final training debrief was structured and guided using the Final

Training Debrief Protocol form (Appendix D) The researcher expected to conduct the interview in-person with each of the participants present as had been done in the previous focus group interviews, but some of the participants advised of their preference to take more time to respond to the interview questions. The researcher agreed and the participants were asked to type their answers directly into the Final Training Debrief Protocol form. Participants returned the forms to the researcher via email.

The Final Training Debrief also provided the participants the opportunity to ask questions or inquire about clarification on any aspect of the training regimen and the data collected, as well as to offer additional feedback and input on the training experience encountered. Additionally, it afforded the researcher the opportunity to follow-up and clarify information (member checking) acquired via observations and surveys on the evidence collected through the various strategies used during the training phases.

The participants again completed the GFD Altitudinal Questionnaire at this time to conclude the Post Training Phase. The attitudinal questionnaire asked the participants to answer the same questions as done in the pre-training session. This post-training attitudinal questionnaire provided an opportunity for the researcher to measure any potential changes in participant attitudes and perceptions on the GFD system.

Summary

The researcher designed this study to investigate pilot perceptions and attitudes towards training on glass flight deck systems via the use of scenario-based training strategies. Key components of this study included an in-depth investigation of the training of multiple pilots, observation and examination of their use of GFD systems within a natural training context, the use of multiple data sources, and an emphasis on qualitative data collection, analysis, and interpretation of the results. A qualitative single case study research design was implemented using an embedded case study format with two subgroups to seek answers to the research questions, and used to determine if the goals of the study can be met with the suggested instructional design changes in the training and learning procedures.

Two participant groups were used for the study. Tenured aviation faculty and staff CFIs comprised one group and delivered the training sessions to the participant group. The participants are the second group (pilots), were subdivided into two subgroups – instrument pilots and flight instructors. All participants were screened to meet a strict pilot profile based on past training, current certifications, and currency of flight experience. All pilot learning and training took place in aviation classrooms and laboratories on the Midwestern aviation university.

Study participants were insured of the most ethical consideration possible. They were fully informed of the scope, nature, and intent of the study. A signed informed consent form was collected from each participant, insuring their complete understanding of study protections and participation expectations. Complete disclosure of all survey and interview data collection efforts was made, and participants were given the opportunity to review and revise the data collected. Given the nature of the training, complete anonymity was assured for each participant, and no participant personal identity information will be disclosed. Full IRB approval was acquired from both institutions with which the researcher is a member.

The researcher assumed the primary roles of evaluator and interpreter for this study. Additionally, the researcher sought to employ the skills of being a good listener and a good questioner emphasizing efforts to "hear" the participants' words, and often probed deeper into their words for additional meanings. Striving to maintain the highest ethics, the researcher regularly did a self-check to insure potential bias or predisposed orientation would not influence analyses and the resultant findings. The researcher implemented strategies to insure prior pilot training and educational experiences, and the professional workplace experience was managed properly to avoid biasing the study process, findings, and final report.

As the primary aim of the study was to better understand pilot perceptions and attitudes throughout SBT training sessions on GA glass flight deck systems, a structured and programmatic set of training phases was well defined and followed. The participants were taken through both a pre- and post- training phase, and two extensive and distinct phases of training involving traditional textbook and classroom lectures, interactive computer-based training modules, partial task training on flight training devices, and complete flight scenarios on flight simulators. At each phase culmination, one or more data collection strategies were employed.

Multiple sources of case evidence were collected. Data collection strategies included observations and field notes, surveys, and interview data from flight debriefs. Each training phase had at least two data collection strategies applied. The qualitative data collected were analyzed for codes and themes and triangulated to confirm validity. Survey data were the only quantitative data collected, and statistically analyzed. Some scenario flight training data were also captured that were statistically analyzed.

Reliability and validity measures were monitored and insured throughout the study. Validity of data was assessed through the evidence convergence and data triangulation of the multiple data sources. Reliability was insured throughout via the use of member checking and peer reviews. Strict controls were placed on data collection, analysis, and storage process for all evidence collected, all for which reliability and validity should be further improved.

Chapter 4

Results

Overview

The training regimen was completed during a two-day period in March 2015 during the University's spring break. The schedule of training events and activities occurred exactly as designed, and other than minor modifications as noted below, all training was executed as planned. During the initial day of training, the traditional classroom lectures, presentations, and CBT part task training exercises were completed with no significant problems. The training environment setting was well planned and organized, and participants had sufficient time and space to progress through the first day's individual training modules.

Data Analysis - Sequencing of Events

Reiterating the three types of data collections strategies from the Methodology chapter, the following list identifies the processes used to capture data from the execution of the study's training regimen:

1. Field note observations – researcher's handwritten notes of observations during training sessions, the computer-based training (CBT) and practice flight, and the flight training device (FTD) scenario-based flight – all of which were transcribed into digital format
2. Survey data – collected via Qualtrics for:

    a.) Participant demographic and pilot profile information

b) Pre-and Post-training participant attitudes toward GFDs

c.) CBT Usability (via the SUS survey)

d.) FTD Usability (via the SUS survey)

3. Interview data – two types:

   a.) Researcher's handwritten notes from focus group discussions on experience following both CBT and FTD flights – which were transcribed into digital format

   b.) Participant-typed notes on overall training experience - paper-based Q&A at end of study – preserved in digital format

Collection of the data occurred throughout the training phases, and CBT and FTD flight tasks and flight scenarios. The discussion of findings integrates the various data collection events as captured. The findings are presented as follows:

1. Participant / Pilot Demographics Questionnaire
2. CBT GFD systems training
3. Group Interview of CBT training and practice flight experience
4. FTD Scenario-based GFD system training
5. Comparison of CBT and FTD GFD Systems – SUS, Usability, and Learnability Ratings by Participant
6. FTD Scenario-based Flight Segment Duration Analysis
7. Group Interview of FTD Scenario-based Flights experience
8. Participant Responses – Pre- and Post-training GFD Attitudinal Survey

9. Interview of participants individually (paper-based Q&A) of overall training experience

A summary review of the researcher's observations is outlined. Comparisons of participants' SUS scoring of the GFD training systems (CBT and FTD) are presented and examined. The results of the qualitative analysis of the flight debriefs and training experiences of the participants are discussed. The participants' pre- and post-training attitudes surveys are also reviewed.

Findings

On the first day prior to beginning the training regimen, the researcher reviewed the purpose and scope of the study with participants. All participants reviewed and signed the informed consent forms. Participants also completed a pilot demographics and attitudinal survey. Of the original 11 participants selected, four participants eventually did not participate in the training due to personal issues. Interstate travel delays kept one participant from participating. Two participants took ill, and one had a family emergency and had to travel out of state during the study period. The remaining seven participants completed all phases of the training regimen, and all survey and interview protocols.

Participant / Pilot Demographics Questionnaire

The demographics of the participant group were captured via the Pilot Demographics and Attitudinal Questionnaire. (A copy of the questionnaires can be found in Appendix E) Questions asked included specifics regarding current academic and current pilot status, licensure, and ratings. Detailed flight hours logged for licenses and ratings were requested, and hours of flight experience with GFD systems were collected.

Academic Standing and Pilot Licensure and Ratings

All participants were holding a junior or senior academic standing in their university Bachelor of Science degree program, and six of the seven participants are aviation degree-seeking majors in the professional pilot/flight officer program pursuing commercial flight careers in aviation. Although gender was not relevant to the study, the group consisted of two females, and five males. Four participants were licensed private pilots (P) currently working towards their instrument rating (I). The fifth participant was preparing to begin commercial pilot (C) license training, while the two remaining participants were further along in their pilot training holding multi-engine ratings. One of these two was also working towards a certified flight instructor license (CFI), while the other one had completed certified flight instructor licenses for both visual and instrument flight rules (CFI-I) in the past few months. Table 6 shows a demographic summary of the participants.

Table 6

Academic Standing/Degree Track, Pilot Licensure/Ratings, Flight Hours, and CFI Status

	Academic Status	Major Degree Track	Licenses & Ratings	Flight Hours Logged	CFI Rating Status
P#1	Senior	Professional Pilot	P -> Inst	155	none
P#2	Senior	Professional Pilot	P -> Inst	120	none
P#3	Junior	Professional Pilot	P, I	104	C next step
P#4	Senior	Professional Pilot	P, I, C, ME, CFI	379	CFI-I in progress
P#5	Senior	Land Use & Cartography	P -> I	80	none
P#6	Junior	Professional Pilot	P -> I	116	none
P#7	Senior	Professional Pilot	P, I, C, ME	410	CFI in progress

Note: Participants' educational and flight demographics as self-reported on the Participants /Pilots Demographics Questionnaire.

Participants' reported flight experiences were scrutinized for reasonableness. Flight hours reported by participants for their certifications and ratings were found be consistent with FAA expectations and the university's aviation department extensive 35+ years of experience educating pilots acquiring such ratings and certificates. No anomalies or inconsistencies were evident.

GFD Experience

The Pilot Demographics Questionnaire also asked the participants to report total flight hours (logged) of experience in real-world GFD systems in both visual flight and instrument flight conditions. Visual flight conditions are flight conditions wherein the pilot can navigate by maintaining visual contact with objects on the earth's surface. Essentially this is being able to see and reference the horizon (i.e. where sky and land meet), to keep earth's landforms in sight, and fly free and clear of clouds - typically referred to as flight under visual flight rules (VFR). Instrument flight conditions are described as having to navigate the aircraft where visibility is reduced, with flight often conducted only by reference to the instruments inside the aircraft, and not being able to maintain visual contact with the earth's horizon or landforms. This type of navigation, defined as flying under instrument fly rules (IFR), is referenced as 'flying in the clouds'. (See Definition of Terms section.) Table 7 summarizes the participants and their flight experience with GFD systems in VFR and IFR flight conditions.

Table 7

Actual GFD System Flight Experience – VFR and IFR Flight Conditions

	GFD System Flight Hours - VFR Conditions	GFD System Flight Hours - IFR Conditions
P#1	6-10 hours	0-5 hours
P#2	6-10 hours	0-5 hours
P#3	11-25 hours	0-5 hours
P#4	0-5 hours	0-5 hours
P#5	0-5 hours	0-5 hours
P#6	6-10 hours	0-5 hours
P#7	0-5 hours	0-5 hours

Note: Participants' educational and flight demographics as self-reported on the Pilot Demographics Questionnaire.

With respect to experience in visual conditions, three participants 0-5 flight hours with GFD systems, while three participants had 6-10 hours GFD experience. Only one participant had 11-25 hours of flight experience in aircraft with GFD systems during visual conditions. Participants reported very limited experience with GFD systems in flight conducted in instrument conditions. All seven participants reported 0-5 hours of flight experience with flight using GFD systems in actual instrument conditions. This result is striking considering this includes even those participants with more than 300 total flight hours, and holding commercial licenses. All seven participants had very little flight time in aircraft with GFD systems; no participant logged more than 30 total flight hours (visual plus instrument combined) in aircraft with GFD systems. Considering the reported visual and instrument flight experiences combined, clearly this group of participants had limited experience with GFD systems in either visual or instrument conditions.

A final question of participants' demographics questionnaire gave them the opportunity to offer any comments on their general attitude on participating in the study's training on GFD systems. Comments generally indicated excitement with the training opportunity to learn how to use GFD systems. One participant offered that his experience was limited, that GFD systems were a great resource to have, but offered, "…it can also be detrimental if you do not understand what is happening and you get caught up the programming and lose track of flying the plane". Another participant noted that GFD systems "used to intimidate me", and that now as a flight instructor having to teach pilots with GFD systems already present in the training aircraft, noted they "would like to become more familiar and comfortable with it" and "hoping this (training) will fix that". After completing the Pilot Demographics Questionnaire, the participants took a short attitudinal survey prior to starting the lecture and CBT-based training sessions.

CBT GFD Systems Training

The researcher kept field notes of his observations for all of the training phases. Following the pre-training orientation session, the CFI gave lectures delivered in small segments to the participant group using an established custom-built aviation CBT systems laboratory. The lectures provided an overview of the GFD system, outlines of the GFD subsystems used in the execution of CBT flight tasks, and a preview of the forthcoming SBT flight scenario. The CFI also demonstrated portions of actual flight segments or "legs" on the instructor's CBT workstation while the individual participants completed essentially the same tasks and workflows. Following the demonstrations by the CFI, participants executed a basic flight scenario that involved the various part-task fight segments that would, when taken together, would be typical of an entire flight plan.

The training setting was subdued and all participants attended. Participants were engaged working the flight tasks, asking numerous types of questions and making comments throughout the CBT flight tasks and scenario training. A few of the questions and comments related to manipulating the GFD training program while getting started. For example, questions posed or comments made included “I’m not finding the start program icon!”, or “Can you dim the screens?”, and “How do you move the cursor around?”.

Participants asked several questions reflecting explanations on aspects of the GFD buttons or about ways to enter data into the GFD system, such as “How do you enter a frequency from the airport list into the comm one radio?”, “How do I get the approach to be active?”, or “How do I get the heading bug or ALT to change?”. Often they were exploring or looking for meaning to on-screen messages and color-coded text such as “Armed nav versus heading mode conflict - to what does that mean?”, “What is the BOD in one minute?”, and “If these are in red why is that?”. Participants also asked for explanations of why certain functions did not seem to work, including “When I activated approach it didn’t give direct to waypoint?”, “Map pages changed from the North track to heading-up orientation change - why?”, and “Why isn’t it following the wings in the flight director?”.

Researcher observations recorded that all CBT training modules were completed on the first day; it appeared that there was no problem with the length or content of the material for each session. Following the cessation of the CBT flight training session, participants took the CBT SUS survey and the researcher noted participants had no problems the online survey forms. The participants then proceeded to the conference room where a group discussion occurred on the training and learning experience with the flight tasks on the CBT systems. The participants seemed a bit reluctant to answer questions in depth, choosing to answer in short phrases; this is reflected in the interview data for this session. Overall, based on the researcher's observation field notes, the general tenor of the CBT training sessions, practice flights, survey and interviews, were all very positive. The researcher concluded the CBT GFD systems training phase was executed as planned.

CBT Usability Survey - GFD Training System SUS Scores, Error Checking, and Handling Inconsistent Scoring

Participants answered ten questions regarding the usability and learnability of CBT GFD training system after completing the lectures and hands on flight task activities. The researcher used the Systems Usability Scale (SUS) survey created by John Brooke (1996). An established usability measurement tool, the SUS survey was used to capture the participants' perspectives on usability and learnability.

The researcher analyzed the SUS survey data using the SUS calculator – an Excel workbook containing a series of spreadsheets created by Jeff Sauro (2011) – that automate the analysis of the data. The SUS calculator system has a number of built-in error checks, including calculations and measures of the internal reliability and validity (i.e. Cronbach's alpha, confidence intervals, comparative tests, etc.). Table 8 presents the summary data for the CBT GFD training system, with values from the automated SUS calculator and error checking for the CTB Usability surveys.

Table 8

CBT GFD Training System: SUS Scores and Error Checking

SUS Mean Score: 59.6		Coding Check:
Standard Deviation: 13.0		Values appear to coded correctly from 1 to 5
Cronbach Alpha: 0.762		Internal Reliability: Good
Scales (as calculated from the 7 participant surveys)		
SUS Mean Score	Usability Mean Score	Learnability
59.6	64.7	39.3

Note: Summary data for CBT GFD SUS as calculated using the Sauro SUS Excel Calculator automated worksheets. Overall mean, standard deviation, and Cronbach Alpha calculated with all seven data sets included.

Reviewing the seven participant surveys, the researcher determined all surveys were answered completely (no missing values or entries). Thus the surveys pass the coding checks. Based on the automated calculations of the SUS calculator, the researcher points to the Cronbach's alpha of 0.762 – an indication of the surveys' internal reliability as being "good".

Participant survey responses were also scrutinized for consistency. One participant survey appeared to have some inconsistent responses that may be a result of the survey respondent rushing through the survey without paying attention, not understanding the questions, or simply misidentifying the level of agreement appropriate for their situation (Sauro, 2011). Inconsistency in one or more of the answers provided on a survey can have an effect on the overall averages for the SUS scores. According to Sauro (2011) different error-handling options exist for dealing with this type of scoring problem, and which option to use is somewhat dependent on total sample size.

It is the researcher's opinion that the impact of the inconsistent score given the few number participants (e.g. a small sample size), is insufficient to warrant elimination of the participant's survey data. The researcher chose to keep the number of data sets consistent between the two usability surveys (CBT and FTD) conducted; this afforded the researcher to maintain consistency in comparing the descriptive statistics between the two GFD training systems.

SUS Scores: Percentile Conversions and Associated Descriptive Ratings

Interpretation of the SUS, usability, and learnability scores is not an exact or perfect science. When comparing any calculated SUS score (individual, overall system, usability, learnability, etc.) to other SUS scores, comparisons can be difficult when looking solely at numerical valuations. One way to counter difficulties with comparing numerical valuations it to use an established descriptive rating system. Sauro (2011) and peers suggested it is best to use descriptive ratings based on SUS percentile rank scores when comparing individual SUS data (Sauro & Lewis, 2009, 2012; Sauro, 2011).

There are no other known SUS scores of either of the GFD training systems used in this study, to which the researcher can make direct scores comparisons. When looking solely at numerical valuations, the comparison of the participants' raw SUS scores can be difficult to assess, or may be blurred or vague. Following Sauro's (2011, 2012) advice, it is more meaningful and valuable to compare SUS scores using descriptive ratings that based on percentile conversions of SUS scores. Percentile rank scores are given an adjective descriptor or rating going from lowest to highest (i.e. Marginal/Poor, Acceptable, Average, Good, Best, etc.)

as a way of identifying how well it compares to other SUS scores, global system interfaces, and other industry systems interface benchmarks.

Table 9 shows SUS scores converted to percentile scales with corresponding descriptive ratings (Sauro and Lewis, 2012). Using the percentile conversion and descriptive ratings table, CBT and FTD GFD system usability scores have been compared more effectively throughout Chapter 4. Descriptive ratings allow the researcher to more effectively compare SUS scores between participants, as well as compare SUS sub scale scores of usability and learnability, for and between the CBT and FTD GFD training systems.

Table 9

GFD Training System Mean SUS Scores: Percentile Conversion and Associated Descriptive Ratings

GFD Mean SUS Score	Converted Percentile Score	Descriptive Rating
80.8 – 100	90 – 100	Best
74.0 – 80.7	70 – 89	Good
65.0 – 74.0	41 – 69	Average
51.7 – 64.9	15 – 40	Acceptable
< 51.7	0 – 14	Marginal/Poor

Note: Researcher-converted GFD training system SUS scores to percentile rank scores for descriptive ratings, as adapted from Sauro's (2011) A Practical Guide to the System Usability Scale.

For example, according to the above table values, a system with a score of 69 is "Average", and has a SUS score that is at least higher than 40 percent of all systems tested with the SUS survey. A system with a score of 77 is "Good" – meaning it has a SUS score higher better than at least 70 percent of all global systems tested. Sauro (2011) points out that while there are differences of a few points between different interface types, most differences are minimal when compared across a variety of hardware or interface systems and devices. Sauro (2011) also points out that attaining a rating of “Best” remains quite difficult albeit possible.

CBT GFD SUS Scores: Percentile Conversions and Associated Descriptive Ratings

Reflecting on participants’ mean SUS scoring summarized in Table 8, and applying the percentile conversion and descriptive and ratings from Table 9, the overall CBT GFD training system mean SUS score of 59.6 would indicate that the CBT GFD system rated as “Acceptable”. This means it scored better than approximately 40 percent of all global systems scored with the SUS survey. Looking solely at the mean usability subscale score of 64.7, participants rated the usability of the CBT GFD training system a bit higher giving it an “Average” rating. Regarding the participants’ scoring of the subscale of learnability with the CBT GFD training system, they rated the CBT GFD system to be “Marginal/Poor”.

Participants’ Individual CBT GFD System Scores

When looking at the individual participant scores, it becomes clear that there is considerable variance in their SUS scores. This applies not only for the overall SUS scores, but for the usability and learnability subscale items, as well. Table 10 presents the descriptive ratings as derived from the seven participant scores, showing the variance in their opinions on the CBT GFD system overall usability. Subscale scores of usability and learnability for the group as a whole are also provided.

Table 10

CBT GFD Training System: Number of Participant Descriptive Ratings of Overall Usability, and Subscales of Usability and Learnability

DR	Overall SUS	Usability Subscale	Learnability Subscale
Best	-	1	-
Good	-	1	1
Average	4	2	-
Acceptable	1	1	1
Marginal/Poor	2	2	5

Note: Individual participant scores were derived from each of the CBT GFD SUS surveys.
*DR=descriptive rating based on Mean SUS score converted to percentile score.

It is instructive to review, compare, and summarize the individual participant survey scores for patterns or trends. As can be seen from the table above, no participants rated the overall CBT GFD system above Average. Two participants rated the CBT GFD training system as “Marginal/Poor”, one rated the CBT GFD system as “Acceptable”, while the over half of the participants (four) rated it “Average”. Variance in scores was found when breaking down the survey subscale items measuring usability and learnability. The participants scored the survey items measuring usability moderately higher, with two participants rating the usability of the CBT GFD system as “Good” (74-80 range), and one participant rating it “Best” (80 or higher). Learnability, a first-time use measure, saw more consistency in scores with five of the seven participants rating the CBT GFD system as “Marginal/Poor”, while one participant each rated the learnability of the CBT GFD training system as “Acceptable” and “Good”. A cursory view of these data shows how just two participant surveys had a considerable impact on the over mean scores. These data indicates there is a good difference in opinion and attitude between the participants regarding the CBT GFD trainings system's usability and learnability.

Group Interviews of CBT GFD Systems Training

The researcher held focus group interviews immediately following the participants completion of the CBT usability surveys. Identified as CBT flight debriefs, the participants assembled in a 12-person conference room away from the training laboratories. All participants sat around the conference room table while the researcher asked questions directly off the focus group interview protocol form. (See Appendix D for a copy of the Flight Debrief Protocol form used.)

The Flight Debrief Protocol form consisted of five questions pertaining to the CBT flight tasks and scenarios completed. The participants answered in the focus group setting. Covering different topics, the participants took turns offering their perspectives and giving answers after each question was presented. Participant answers were generally short phrases and sentences, although long answers were occasionally given. The group as a whole heard each question, and participants answered in random order - no special or predefined sequence of soliciting answers was attempted. Participants also had the opportunity to offer final comments after each one had answered the topical question addressed to the group as a whole, both to share additional information and to clarify previous comments or an answer. Occasionally participants would offer additional comments when going around the table to solicit additional perspectives or clarifications.

CBT Flight Debrief - Qualitative Data Analysis

The responses of the participants were transcribed verbatim into MS Word directly from the Flight Debrief Protocol form. The researcher prepared the documents for qualitative data analysis with NVivo. NVivo was used to facilitate the researcher in analyzing the participants responses to the flight debriefs completed in the focus group interviews, and the opened ended questions of final training debrief interview. The flight debrief questions served as a starting point for eliciting participants' perceptions and attitudes towards their training on the CBT GFD system, the use of scenario-based tasks and exercises, and their user experiences (e.g. usability and learnability) with the CBT GFD training system.

NVivo aided the researcher in organizing participant responses, coding the responses into common terms and groups, and building thematic maps from the coded groups, all of which traditionally used to be completed by hand on paper. The codes and themes helped the researcher to see patterns through the building of visual maps, graphs, and word trees.

The participants' responses were primarily very short phrases and this made rich coding and theme building a bit difficult given the limited amount of data. However, the participants provided consistent and similar information in their responses, in both positive and negative comments, and themes that could be mapped visually. Figure 6 is a visual map of the themes that reflect an overview of the participants' perspectives. The dominant theme uncovered was that the overall training experience with the CBT GFD system was quite positive.

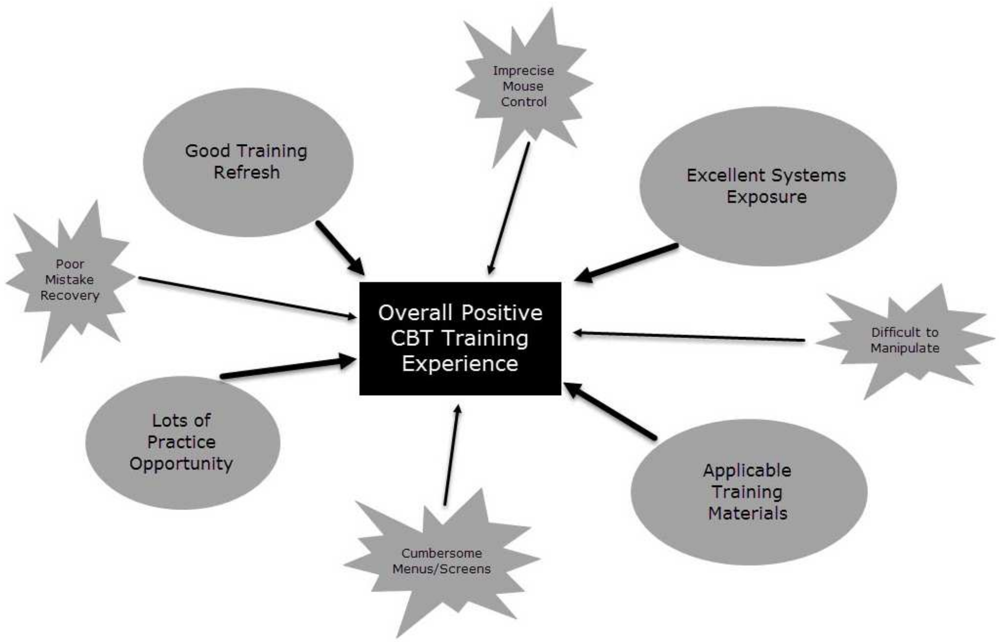

Figure 6. CBT Overall Training Experience – Visual Map. Participant perceptions, negative and positive, that generated their overall positive training experiences with the CBT GFD training system as reported during group interviews and debrief, after the CBT training concluded.

The visual map of the codes and themes, Figure 6 provides a good overall perspective of the participants training experiences with the CBT GFD system. Summarizing the visual map, participants reported both positive and negative perceptions and attitudes with the CBT GFD training system, but overwhelmingly reported the training was positive and had lasting impact on their knowledge and learning of the GFD system and transferring over to their training with the FTD GFD system. Participants' predominantly reported positive perceptions, attitudes, and results with the training and their positivity are reflected in the themes with larger round or oval shapes with bold print. For example, positive themes uncovered included the training was good for refreshing past training, provided lots of opportunity to practice, and the training materials directly applied to more thorough learning of the multiple GFD systems. Negative codes and themes emerged as well, but were much less frequent, albeit similar and consistent among the participants. Negative themes discovered included problems with the CBT systems input interfaces (primarily mouse and keyboard) and cumbersome menus making it difficult to manipulate the program, and poor user error recovery in the software when entry mistakes were made. Negative themes are the small starred shapes, with light print reflecting their infrequency and lesser impact on the participants' perceptions and attitudes.

FTD Scenario-Based GFD Systems Training (SBT Flights)

The researcher recorded field notes, as was done for the CBT GFD flight tasks and training objectives, while observing the participants prepare, setup, and fly the scenario-based flights on the flight training devices (FTDs). These field note observations provided a convenient way to watch over each participant's flight without interfering or interjecting while the participant concentrated on completing the flight scenario plan as required. In addition to the researcher's field note observations, additional useful data emerged for each participant on the specific SBT flight subtasks. The additional data resulted in informing descriptive statistics recorded from the CFI's flight scenario protocols that were used to manage the flow of each participant flight scenario, and are presented in a following section.

The schedule established for the execution of the SBT flights by the individual participants generally occurred with little to no problems or disruptions. Participant acted as if they had arrived at the airfield ready to prepare and organize a fully fueled and airworthy aircraft for the prescribed flight. Each participant received a complete flight plan packet with the entire flight plan data needed to complete the flight as scheduled, and received up to 15 minutes to review the flight plan, request additional information, or ask any questions desired.

Although the setup and flight plan entry times varied for each participant, most participants went about their business with what the researcher perceived as a level of confidence and attitude of knowing what they were doing. Most seemed quite focused and immersed in working through the individual flight legs and entering the GFD system settings and parameters needed to be successful for each flight segment or phase. Throughout the scenario-based flights, all the participants talked aloud to themselves as they worked through the flight plan segments or legs. Occasionally a few of the participants would become quiet, appearing to be absorbed trying to assess what to do, or how to manipulate the GFD system for a desired result.

Only one participant seemed to encounter multiple problems using the GFD system during the entire flight scenario. A few of the participants reverted to their prior training that teaches when trouble or confusion arises with complex equipment inside the flight deck, to go back to the basics of flying the aircraft – a positive and proven approach when dealing with complex aviation equipment.

FTD Usability Survey – GFD Training System SUS Cores, Error Checking and Handling Inconsistent Scoring

Following the completion of the FTD SBT flight, each participant again answered ten questions regarding the usability and learnability of FTD GFD training system. The researcher again used the Systems Usability Scale (SUS) survey. This survey was used capture the participants' subject perspectives on usability and learnability of the FTD GFD training system. Identical to the analysis process used for the CBT GFD training system SUS data, the researcher analyzed the FTD GFD training system data Sauro's (2011) SUS calculator – the Sauro Excel workbook. Table 11 presents the summary data for the FTD GFD training system, with values from the automated SUS calculator and error checking for the FTD GFD SUS dataset.

Table 11

FTD GFD Training System: SUS Scores and Error Checking

SUS Mean Score: 52.9		Coding Check:
Standard Deviation: 15.1		Values appear to coded correctly from 1 to 5
Cronbach Alpha: 0.851		Internal Reliability: Good
Scales (as calculated from the 7 participant surveys)		
SUS Mean Score	Usability Mean Score	Learnability
52.9	59.4	26.8

Note: Summary data for FTD GFD SUS as calculated using the Sauro SUS Excel Calculator automated worksheets. Overall mean, standard deviation, and Cronbach Alpha calculated with all seven data sets included.

Reviewing the seven participant surveys, the researcher determined all surveys were answered completely (no missing values/entries), and thus the surveys pass the coding checks. Based on the automated calculations using the SUS calculator, the researcher points to the Cronbach's alpha of 0.851 – and measuring of internal reliability of the surveys as quite good.

Participants' survey responses were again scrutinized for consistency. Unlike the CBT GFD survey, no participant surveys appear to have inconsistent responses. Therefore, the SUS mean score, the usability mean score, and the learnability mean score required no evaluation for error corrections or modifications. These scores allow for a direct comparison (in a later section) of the CBT GFD SUS scores with the FTD GFD SUS scores. Recall that percentile rank scores are given an adjective descriptor or rating going from lowest to highest (i.e. Marginal/Poor, Acceptable, Average, Good, Best, etc.) as a way of identifying how well it compares to other SUS scores, global system interfaces, and other industry systems interface benchmarks available.

FTD GFD SUS Scores: Percentile Conversions and Associated Descriptive Ratings

As done with the CBT GFD scores, the researcher converted the raw FTD GFD training system SUS scores to percentile rank scores to make the comparisons presented in following sections. The percentile conversions for the FTD GFD training system mean SUS scores rendered the same percentile ranges for scores for the CBT, and thus the same descriptive ratings are applicable. Looking at these tabular values and ratings, one can see the FTD GFD training system scored noticeably poorer than the CBT GFD training system for all three measures (the overall SUS score, the usability subscale score, and the learnability subscale score).

Reflecting on participants' mean SUS scoring summarized in Table 11, and applying the percentile conversion and descriptive and ratings from Table 9, the overall FTD GFD training system mean SUS score of 52.9 would indicate that the FTD GFD system rated as "Acceptable". This means it scored better than approximately 47 percent of all global systems scored with the SUS survey. Looking solely at the mean usability subscale score of 59.4, participants rated the usability of the FTD GFD training system a bit higher but still only receiving an "Acceptable" rating. Regarding the participants' scoring of the subscale of learnability (26.8) with the FTD GFD training system, they rated the FTD GFD system to be "Marginal/Poor".

Participant's Individual FTD GFD System Scores

When looking at the individual participant scores, it becomes clear that there is a general trend downward in ratings, for both the overall FTD GFD system scores and for the usability and learnability subscale items, as compared to CBT GFD system scores. This is reasonable and consistent given the overall lower global SUS scores and ratings presented in the previous section. Table 12 presents the descriptive ratings as derived from the seven participant scores, showing their opinions on the FTD GFD system overall usability, as well as the subscale scores of usability and learnability for the group as a whole. The descriptive ratings used were derived by the converted percentile scores presented as Table 9.

Table 12

FTD GFD Training System: Number of Participant Descriptive Ratings of Overall Usability, and Subscales of Usability and Learnability

DR	Overall SUS	Usability Subscale	Learnability Subscale
Best	-	1	-
Good	-	1	-
Average	2	1	-
Acceptable	1	2	-
Marginal/Poor	4	2	7

Note: Individual participant scores were derived from each of the FTD GFD SUS surveys.
*DR=descriptive rating based on Mean SUS score converted to percentile score.

Two participants scored the overall usability of the FTD GFD training system as "Average". One participant scored the FTD GFD training system as "Acceptable". Of note, however, the remaining four of the participant group rated the usability of the FTD GFD training system as "Marginal/Poor".

It is also instructive to review and summarize the individual participant FTD GFD survey scores for the subscales of usability and learnability. As can be seen from the ratings above, the FTD GFD survey items measuring usability and learnability notably trended downward similar to the overall FTD GFD SUS scores, when compared the CBT GFD system scores. Although two participants rated the subscale of usability for the FTD GFD training system as "Good" or "Best", the rest of the participant group (four) rated the FTD GFD training system downward with a rating of "Acceptable" or below. The subscale of learnability (the first-time use measure), however, showed the biggest downward rating trend, with all participants rating the FTD GFD training system as "Marginal/Poor".

Comparisons of CBT and FTD GFD Systems – SUS, Usability, and Learnability Ratings by Participant

One last set of valuable comparisons of the CBT and FTD GFD training system ratings can be made. By looking at the individual participant ratings for both the CBT and FTD GFD systems, one can get a sense of the differences of the individual participant perceptions in their learning and training experience with each of the systems. Table 13 presents a comparison of the overall SUS ratings by each participant for both GFD training systems.

Table 13

CBT and FTD GFD Training System Scores Comparison: Mean Overall SUS Scores by Participant

	CBT GFD Overall Rating	FTD GFD Overall Rating
Participant #1	Average	Marginal/Poor
Participant #2	Marginal/Poor	Average
Participant #3	Average	Average
Participant #4	Average	Marginal/Poor
Participant #5	Average	Acceptable
Participant #6	Marginal/Poor	Marginal/Poor
Participant #7	Acceptable	Marginal/Poor

Note: Individual participant overall ratings for each of the CBT and FTD GFD SUS surveys given.

Looking at the ratings above, there is a downward change in the rating of the FTD GFD system. There also is dissent between the participants to the overall numerical SUS ratings given. While six of seven of the participants rated the systems differently, upon closer inspection only one of the three participants' scores actually changed its descriptive rating in an upward positive direction (going from "Marginal/Poor to Average"). Ultimately, when looking at the descriptive ratings assigned, six of the seven participants all gave the FTD GFD system scores that generally resulted in an overall downgrade towards or to "Marginal/Poor".

A similar pattern exists for the scoring of the subscale of usability. Participants again have shown notable and wide differences in perspectives on the usability of the FTD GFD system. Table 14 presents a comparison of the usability subscale ratings by each participant for both GFD training systems.

Table 14

CBT and FTD GFD Training System Comparison: Mean Usability Scores by Participant

	CBT GFD Usability Subscale Rating	FTD GFD Usability Subscale Rating
Participant #1	Best	Marginal/Poor
Participant #2	Marginal/Poor	Best
Participant #3	Average	Good
Participant #4	Average	Acceptable
Participant #5	Good	Average
Participant #6	Marginal/Poor	Acceptable
Participant #7	Acceptable	Marginal/Poor

Note: Individual participant overall ratings for each of the CBT and FTD GFD SUS surveys given.

Participants' usability subscale ratings between the two GFD systems were markedly different. Interestingly, three participants' ratings showed significant change, going way up or way down in rating, while the other four participant ratings stayed around an "Average" rating with little change. This pattern is similar in the overall SUS scores but certainly not to such a degree. This is consistent with the fact that the usability subscale measures make up eighty percent of the survey items scored. More participant agreement can be seen in the FTD GFD system subscale learnability scores participants recorded. Here there is more consensus in the scoring by all participants, albeit the "Marginal/Poor" rating across the board. Table 15 presents a comparison of the learnability subscale scores by each participant for both GFD training systems.

Table 15

CBT and FTD GFD Training System Comparison: Mean Learnability Scores by Participant

	CBT GFD Learnability Subscale Rating	FTD GFD Learnability Subscale Rating
Participant #1	Marginal/Poor	Marginal/Poor
Participant #2	Marginal/Poor	Marginal/Poor
Participant #3	Acceptable	Marginal/Poor
Participant #4	Good	Marginal/Poor
Participant #5	Marginal/Poor	Marginal/Poor
Participant #6	Marginal/Poor	Marginal/Poor
Participant #7	Marginal/Poor	Marginal/Poor

Note: Individual participant overall ratings for each of the CBT and FTD GFD SUS surveys given.

Participants' ratings showed a significant trend downward. Participants rated the first-time use learnability of the FTD GFD system with all seven participants' rating the FTD GFD training system as "Marginal/Poor" - clearly is a poor showing. With such low ratings given by the participants, it is also clear the overall learnability rating significantly affected overall SUS ratings.

SBT Flights – Duration Analysis

Additional useful data emerged from the records of the CFI flight scenario protocols that were used to manage the flow of each participant flight scenario. The additional data resulted in informing descriptive statistics for each participant on the specific SBT flight subtasks. The CFI made hand written notes in the form of time stamps and simple phrased-based notations for all of the flight segments executed by each of the participants while conducting the scenario-based flight.

The primary notes recorded allowed the CFI to capture time and duration information to enable the CFI to keep the participants “on-task” during the estimated sixty-five minute scenario-based flight plan. The researcher created the flight scenario protocol feeling it was important a.) to limit the potential level of participant stress from problems or frustrations arising or experienced during the flight scenario, b.) to insure each participant experienced essentially the same flight scenario requirements and conditions, and c.) to avoid having excessively long or drawn out flights that would have negatively affected other participant start times for succeeding flights as scheduled. A detailed discussion of the SBT flights duration analysis and statistics can be found in Appendix F.

The additional dataset that emerged was “time-to-complete” data for each participant on the specific SBT flight subtasks (unique segments or “legs” to the flight), and was quite informing. These individual participant “time-to-complete” tasks are time-stamps on the CFI’s flight tracking script used for each of the participant flights. The use of the CFI flight tracking script originally was intended to a.) systematize the CFI’s role as an air traffic controller, b.) keep each participant on a reasonable but demanding flight schedule as might be experienced in the real world, and c.) insure each participant followed the same flight scenario plan, and d.) keep all scheduled flight scenarios on time (start and end). This also allowed the researcher to insure the scenario-based flights stayed relatively on schedule as would occur in the real world.

Upon review of the timing and duration data, five different time stamps were captured for the various segments or "legs" of the flight scenario. Calculations for duration of time between these time stamps for key flight segments rendered simple statistical information for each of the participants. An overview of the flight leg segments and related duration of select flight tasks in the FTD GFD flight scenario is presented in Figure 7.

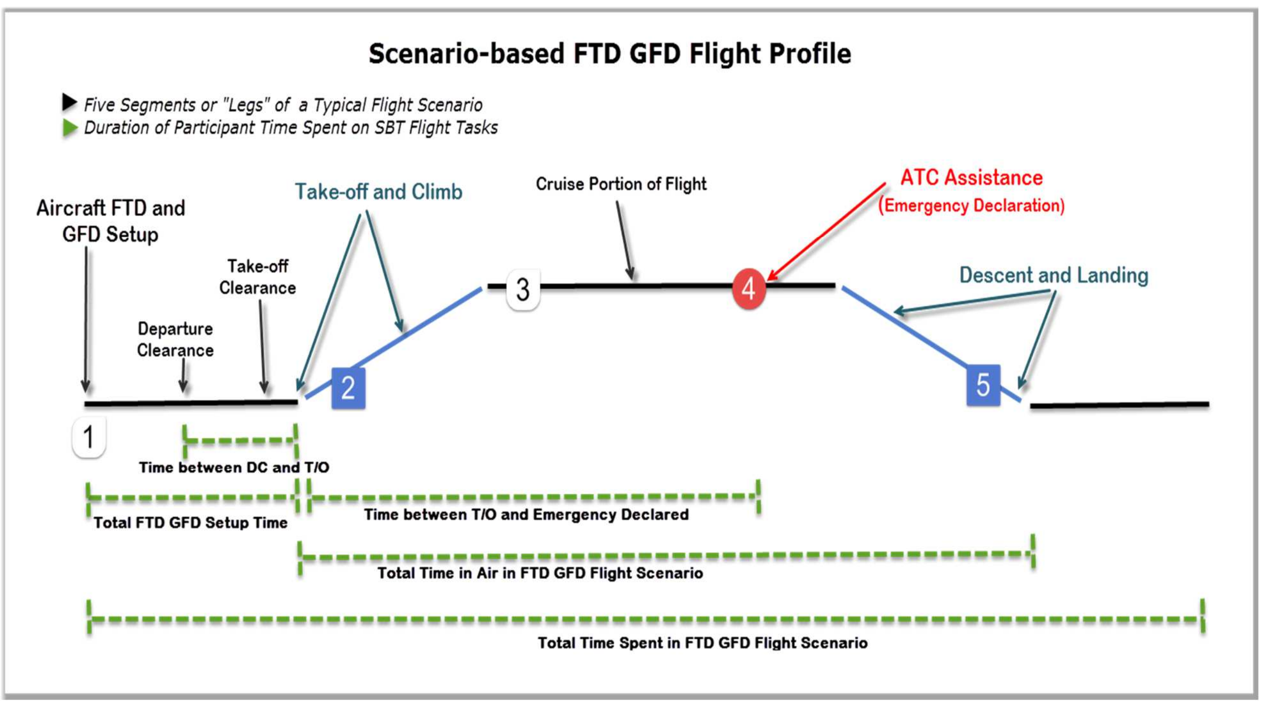

Figure 7. Scenario-based FTD GFD Flight Profile: The Five Flight Segments or Legs of the Scenario-based Flight and Participant Time Spent on SBT Flight Tasks.

From Figure 7, the researcher calculated the duration of the five flight scenario segments. The five flight scenario segments are listed:

1. Time spent to prepare, utilize checklists, and entering the flight plan necessary to setup the FTD for the flight scenario.
2. Time spent on final aircraft preparation and checks – time between receiving departure clearance and requesting take-off clearance.
3. Time in flight between take-off and declaring emergency and requesting ATC assistance.
4. Time spent in the air in flight from take-off to landing.
5. Total time spent on completing the scenario-based flight – from beginning the FTD setup process to the landing back at the airport.

In general, most of the participants were similar in their time spent to complete the various flight segments, with the exception of one participant who did experience more difficulty than the rest when completing the entire flight scenario. Given one participant did experience approximately 25-30% more time to complete the entire flight scenario compared to the other participants, the researcher calculated two different sets of simple statistics for which are presented in the detailed discussion found in the appendices. Table 16 presents the mean duration times for all participants by flight segment.

Table 16

Mean Duration Times By FTD Scenario-based Flight Segments

SBT Flight Segment (Leg)	Mean Duration Time for Flight Segment(hrs:mins:secs)
Setup Time: Aircraft FTD and GFD Prep and Checklists	22:20
Final Aircraft Check: Time between Departure Clearance and Takeoff	8:36
Emergency Declaration Leg: Time In-flight between Take-off and Emergency Declaration (ATC Support)	21:42
Time In Flight (In Air) Leg: Takeoff to Landing	49:36

Table 16 Continued

SBT Flight Segment (Leg)	Mean Duration Time for Flight Segment(hrs:mins:secs)
Total Time Spent on SBT Flight	1:13:24

Note: Mean times calculated from averaging of all participant times. Detailed individual participant actual times for each flight segment are in the SBT Flights Duration discussion and analysis in Appendix F.

The researcher scripted the original flight scenario to be executed in approximately 60-69 minutes based on real-world flight times. The mean figures above represent figures that are within 10-15% of the scripted time. Therefore, the researcher concluded the participant group mean time figures are appropriate and reasonable for the SBT flight as planned, and reflects what a real world small GA commercial flight using the GFD system would present in such a situation. Furthermore, as no unplanned anomalies or GFD system level problems arose, the researcher can confidently conclude all the participants experienced essentially the same flight scenario and thus their perspectives and opinions discussed in the following sections accurately reflect their experience with the GFD training system used in the scenario-based flight plan.

Group Interview of FTD Scenario-based GFD System Training (SBT Flights)

As was done at the end of the CBT training session, the researcher held focus group interviews immediately following the participants completion of the FTD SBT flights. Identified as SBT flight debriefs, the participants assembled in a 12-person conference room away from the training laboratories. All participants sat around the conference room table while the researcher asked questions directly off the focus group interview protocol form. (See Appendix D for a copy of the Flight Debrief Protocol form used.)

The Flight Debrief Protocol form consisted of five questions regarding the SBT flights, and the participants answered in the focus group setting. Covering different topics, the participants took turns offering their perspectives and giving answers after question presentation. Participant answers were generally more detailed but still short phrases and sentences, compared to the CBT training focus group interview responses. Again, the group as a whole heard each question, and participants answered in random order - no special or predefined sequence of soliciting answers was attempted. Participants also had the opportunity to offer final comments after each one had answered the topical question addressed to the group as a whole, both to share additional information and to clarify previous comments or an answer. Occasionally participants would offer additional comments when going around the table to solicit additional perspectives or clarifications.

FTD Flight Debrief - Qualitative Data Analysis

The responses of the participants were also transcribed (verbatim) into MS Word directly from the Flight Debrief Protocol form. The researcher prepared the documents for qualitative data analysis with NVivo. NVivo facilitated the researcher in analyzing the participants more detailed responses to the flight debrief questions from the focus group interview. As with the CBT Flight Debrief, the FTD flight debrief questions served as a starting point for eliciting participants perceptions and attitudes towards their training on the FTD GFD system, the use of scenario-based tasks and exercises, and their user experiences (e.g. usability and learnability) with the FTD GFD training system. The researcher again used the NVivo software to aid in organizing participant responses, coding the responses into common terms and groups, and building thematic maps from the coded groups.

As the participants' became more comfortable with the focus group interview format, their responses for this flight debrief were in the form of more detailed phrases, compared to their somewhat limited responses during the CBT focus group interview. The detail made for richer coding and theme building, and this is reflected in thematic map presented as Figure 8. The participants again provided consistent and similar information in their responses, in both positive and negative comments, and the themes that were mapped are visually telling. Figure 8 is a visual map of the themes that reflect an overview of the participants' perspectives with respect to their predominately-reported positive training experiences with the overall FTD GFD system.

Figure 8. FTD GFD Systems Best Training Overall – Visual Map. Participant perceptions, negative and positive, that generated their overall positive training experiences with the FTD GFD training system as reported during group interviews and debrief, after the FTD Scenario-based training concluded.

The visual map of the codes and themes, Figure 8 provides a very good overall perspective of the participants training experiences with the FTD GFD system. Summarizing the visual map, participants reported both positive and negative perceptions and attitudes with the FTD GFD training system, but the overarching theme was the FTD GFD training was the best training experience received in their aviation education to date. As denoted by the large oval symbols and bold print, participants' predominantly reported the FTD GFD system as important in fulfilling hands-on training, in providing immediate feedback (success/failure) on GFD behavior, and in developing the demands of focus and concentration when dealing with the integrated GFD subsystems. In constructivist terms, these types of learning experiences are important to building higher order thinking and critical decision-making skills so important pilot training.

Negative codes and themes did emerge however, but were both less frequent and not as significant. Responses were very similar and consistent among the participants. Participants consistently noted that they needed more SBT training on GFD systems to work through the attention diversion issues that arise using a complicated and complex advanced flight deck. They also noted they had gaps in their knowledge of the functions and integration of the various GFD subsystems, and the related complexity of the various menus, buttons, and switches prevalent in GFD systems, but felt that additional SBT training would help them resolve their knowledge gaps.

Participant Responses – Pre-training and Post-training GFD Attitudinal Survey

Participants rated five statements regarding their attitude toward GFD systems, prior to starting any training sessions. Participants were also asked to rate the same five statements following the completion of the training regimen. Statements referred to the GFD system as an "advanced cockpit" – a term frequently used during the training regimen. Given the multiple subsystems found in a GFD system, statement #1 and #2 referred to the unit itself – the GFD system – as a technical and sophisticated device. Statement #3 and #4 referred to the participant's attitude regarding how it relates to their individual piloting skills. Statement #5 referred to the general use of the GFD system during flight.

Pre-training GFD Attitudinal Responses

The GFD Attitudinal Survey statements were presented using a typical Likert scale format. The survey required the participant to select one of five options (e.g. strongly-agree, agree, neither agree nor disagree, disagree, and strongly-disagree) that most closely compared to the participants attitude regarding each statement. Table 17 summarizes the participant attitudes towards each of the statements.

Table 17

Participant GFD Attitudinal Survey Responses – Pre-training

	SD	D	NAD	A	SA
S#1. *They have gone too far with advanced cockpit systems*	1	4	1	1	-
S#2. *I look forward to new kinds of advanced cockpit systems.*	-	-	-	5	2
S#3. *The advanced cockpit system does not make good use of my basic piloting skills.*	2	2	1	1	1
S#4. *In an advanced cockpit, I feel more like a "button-pusher" than a pilot.*	-	3	2	1	1
S#5. *Advanced cockpit systems can get you into trouble as easily as they can get you out of trouble.*	-	-	-	3	4

Note: Detailed tabular data from the GFD Attitudinal surveys were used for this summary table.

Participants' attitudes were quite similar in consensus towards the first two statements. Regarding the sophistication and technology of the GFD system, participants generally responded in disagreement with statement #1 "…have gone too far with advanced cockpit…", and overwhelming agreed with statement #2 "...look forward new kinds of advanced cockpit…". Participant attitudes were not as similar when responding to statements regarding their attitude towards their personal flight skills and GFD systems. Participant attitudes to statement #3 "…advanced cockpit does not make good use of …" were spread across the Likert scale. Similarly, participant attitudes towards statement #4 "In an advanced cockpit, I feel more like a "button-pusher"…", were generally split between agreeing and disagreeing. Statement #5 referred to the use of the GFD system during flight. Participants overwhelming agreed with the statement. "Advanced cockpit systems can get you into trouble as easily as they can get you out of trouble".

Following Statement number 5, the participants were given the opportunity to share their attitude towards learning and using GFD systems. Participant answers were somewhat similar to the answers provided regarding participant attitudes towards the training sessions. Their comments reflect common themes held among the participants, and include their interest in the GFD system, its application in improving their flight skills, and concerns of being able to learn and use the GFD system use effectively. Below are three examples of the most interesting and important comments shared.

If you care to share any particular comments about your general attitude to this study, the training program, or in learning/using glass flight deck systems, please provide your comments below:
"I view learning/using glass flight deck systems are one of the most important skills a modern pilot would need to attain so become fully competent in future systems." "I have used GFDs a little bit and I have found that as long as you understand what you are doing, they are a great resource to have in the cockpit. It can also be detrimental if you do not understand what is happening and you get caught up in the programming and lose track of flying the plane." "I have very little time using GFD. As a new flight instructor and for the direction the industry is going, I would like to become more familiar and comfortable with it. It used to intimidate me. Hoping this class will fix that."

Post-training GFD Attitudinal Responses

Following the completion of the scenario-based FTD GFD training experience, participants rated the same five statements regarding their attitude toward GFD systems, as they did prior to starting the study training sessions. Again, each statement was presented using a typical Likert scale format, asking the participant to select one of five options (e.g. strongly-agree, agree, neither agree nor disagree, disagree, and strongly-disagree) that most closely compared to the participants attitude regarding each statement. Table 18 summarizes the participant attitudes towards each of the statements.

Table 18

Participant GFD Attitudinal Survey Responses – Post-training

	SD	D	NAD	A	SA
S#1. *They have gone too far with advanced cockpit systems*	-	5	1	1	-
S#2. *I look forward to new kinds of advanced cockpit systems.*	-	-	-	5	2
S#3. *The advanced cockpit system does not make good use of my basic piloting skills.*	-	2	2	2	1
S#4. *In an advanced cockpit, I feel more like a "button-pusher" than a pilot.*	1	2	1	3	-
S#5. *Advanced cockpit systems can get you into trouble as easily as they can get you out of trouble.*	-	-	-	3	4

Note: Detailed tabular data from the GFD Attitudinal surveys was used for this summary table.

Regarding statements on the sophistication and technology of the GFD system (device), participants generally responded in concert with each other. Compared to the Pre-training GFD Attitudinal survey responses, only one participant response changed; otherwise, all participants' attitudes remained the same giving responses identical to those offered in the Pre-training GFD Attitudinal survey. Participant attitudes to statement #3 "…advanced cockpit does not make good use of …" were concentrated around the center (disagree-neither agree/disagree-agree) of the Likert scale. Similarly, participant attitudes towards statement #4 "In an advanced cockpit, I feel more like a "button-pusher"…", were generally split between agreeing and disagreeing. Statement #5 referred to the use of the GFD system during flight. Participants overwhelming agreed with the statement, with identical responses to the pre-training survey. "Advanced cockpit systems can get you into trouble as easily as they can get you out of trouble" responses from participants were all either agree or strongly agree.

Again, following Statement number 5 was an open-ended question and answer opportunity for participants to share their attitude towards learning and using GFD systems. Some participant answers were similar to the answers provided regarding participant attitudes towards the training sessions. The answers reflect common themes held among the participants, and include their interest in the GFD system, its application in improving their flight skills, and concerns of being able to use and learn GFD system use effectively. The participant responses were more articulate and descriptive in their attitudes towards using and learning GFD systems. Below are three examples of the most interesting and important comments shared.

If you care to share any particular comments about your general attitude to this study, the training program, or in learning/using glass flight deck systems, please provide your comments below:
"Applying the knowledge learned from the GFD training had an effect of how safe the flight was executed but it did not prepare me for any in-flight emergencies. Although, if scenario CBT based training with the GFD was implemented in the flight, I would have felt more comfortable to handle in-flight emergencies and safely execute the necessary emergency checklist items." "Again, I believe that the GFD systems can be a great asset, but as it showed with my flying after today, it can be very easy to get caught up and start to lose track of what is going on. There were times when I went to look at the map when configuring things and all of a sudden I was on a completely different course in a 60 degree bank."

"The system was very frustrating to take into solid IMC and have an electrical failure with zero experience in a G1000. I as a pilot would never take this plane into IMC by myself until I was very comfortable with all of the systems. I would want an experienced person with if I did. I found myself to be very frustrated with the systems at times, even just starting the plane up."

"I struggled with some of the inner workings of the G1000 while working the emergency but with proper training, I would have been able to have a lower workload."

Pre-training to Post-training GFD Attitudinal Responses Comparison

Given the participants entered the study with pre-established attitudes and perceptions regarding GFD systems, the researcher was curious if participant attitudes towards GFD systems changed after completing the training regimen. A comparison of the participant attitudes regarding the GFD system before the training and after the training revealed some interesting results. The comparison of the GFD surveys of attitudes pre-training and post-training are presented in comparative tables for each of the statements presented.

Recall that the GFD Attitudinal Survey Statements #1 and #2 reflected the GFD system itself as a technical and sophisticated device. Comparing participant responses pre-training and post-training for the first two statements showed very limited changes in participant attitudes. Table 19 shows the pre-training (P_R) and post-training (P_O) Likert scale ratings of the participants regarding their attitudes of the first statement regarding GFD system itself as a technical and sophisticated device.

Table 19

Comparing Participant Attitudes Before and After Training – The GFD System as a Technical and Sophisticated Device (S#1)

S#1: *They have gone too far with advanced cockpit systems.*					
Likert Scale	Strongly Disagree	Disagree	Neither Agree / Disagree	Agree	Strongly Agree
Participant #1	P_R ------	--- > P_O			
Participant #2		P_R -- P_O			
Participant #3		P_R -- P_O			
Participant #4		P_R -- P_O			
Participant #5		P_R -- P_O			
Participant #6				P_R -- P_O	
Participant #7			P_R -- P_O		

Note: Comparison of each participant's attitude rating pre-training (P_R) and post-training (P_O). The arrow shown indicates the direction of change.

With the exception of two participants, most participants generally held disagreement with the statement, and maintained their disagreement following training. As can be seen from above, only one of the participants actually changed their attitude regarding "they have gone too far with advanced cockpit systems" – and the participant's attitude appears to have softened in disagreement after completing the training.

Comparing participant responses pre-training (P_R) and post-training (P_O) for Statement #2 showed some limited changes with attitudinal movement about the Agree/Strongly Agree range of participant attitudes. Table 20 shows the before (P_R) and after (P_O) Likert scale ratings of the participants regarding their attitudes of the second statement regarding GFD system of the GFD system itself as a technical and sophisticated device.

Table 20

Comparing Participant Attitudes Before and After Training – The GFD System as a Technical and Sophisticated Device (S#2)

S#2: *I look forward to new kinds of advanced cockpit systems.*					
Likert Scale	Strongly Disagree	Disagree	Neither Agree / Disagree	Agree	Strongly Agree
Participant #1				P_O < ---	------ P_R
Participant #2				P_R ------	--- > P_O
Participant #3				P_R ------	--- > P_O
Participant #4				P_R -- P_O	
Participant #5				P_O < ----	------ P_R
Participant #6				P_R -- P_O	
Participant #7				P_R -- P_O	

Note: Comparison of each participant's attitude rating pre-training (P_R) and post-training (P_O). The arrow shown indicates the direction of change.

All participants were in agreement with looking "forward to new kinds of advanced cockpit systems", with most agreeing with the statement. Following completion of the training, limited adjustment of participants' attitudes can be observed within the Agree/Strongly Agree range. What attitudinal changes that did occur were essentially balanced out by the group overall.

Recall that the GFD Attitudinal Survey Statements #3 and #4 reflected how the GFD system relates to the individual participants' piloting skills. Comparing participant responses pre-training (P_R) and post-training (P_O) for these two statements showed greater changes in movement of attitudes about the Strongly Disagree/Disagree range, and towards the agreement ranges. Table 21 shows the before (P_R) and after (P_O) Likert scale ratings of the participants attitudes of the GFD system and how it relates the first statement regarding their individual piloting skills.

Table 21

Comparing Participant Attitudes Before and After Training – The GFD System and How It Relates to Individual Piloting Skills (S#3)

S#3: *The advanced cockpit system does not make good use of my basic piloting skills.*					
Likert Scale	Strongly Disagree	Disagree	Neither Agree / Disagree	Agree	Strongly Agree
Participant #1	P_R ------	----------------	----- > P_O		
Participant #2		P_R ------	----------------	----- > P_O	
Participant #3	P_R ------	----- > P_O			
Participant #4		P_O < ---	------- P_R		
Participant #5		P_R ------	----- > P_O		
Participant #6				P_R ------	----- > P_O
Participant #7				P_O < ---	------- P_R

Note: Comparison of each participant's attitude rating pre-training (P_R) and post-training (P_O). The arrow shown indicates the direction of change.

This statement elicited more differences in attitudes among the participants regarding the GFD system "not making good use of their pilot skills". Following training completion, all participant attitudes adjusted a bit, with all four of the participants that originally fell in the disagreement range, softening their disagreement moving towards the center of the Likert scale (neither agree/disagree). One of the participants that started the training in the Agree range also moved right – and these shifts towards more agreement with the statement is an indication the five participants felt the GFD system was less effective at “making good use of their pilot skills”. Two of the participants however did soften their agreement with the statement as post-training attitudes for these two participants moved to the left of the Likert scale.

Now, comparing participant responses pre-training (P_R) and post-training (P_O) for Statement #4 shows participant responses evenly spread out between disagree, neither agree/disagree and agree scales. Table 22 shows the before (P_R) and after (P_O) Likert scale ratings of the participants regarding their attitudes of the GFD system and how it relates to the second statement regarding their individual piloting skills.

Table 22

Comparing Participant Attitudes Before and After Training – The GFD System and How It Relates to Individual Piloting Skills (S#4)

S#4: *In an advanced cockpit, I feel more like a “button-pusher” than a pilot.*					
Likert Scale	Strongly Disagree	Disagree	Neither Agree / Disagree	Agree	Strongly Agree
Participant #1		P_R ------	----------------	---- > P_O	
Participant #2				P_R -- P_O	
Participant #3	P_O < ----	------- P_R			
Participant #4		P_O < ----	------- P_R		
Participant #5			P_R -- P_O		
Participant #6		P_R -- P_O			

Table 22 Continued

S#4: *In an advanced cockpit, I feel more like a "button-pusher" than a pilot.*					
Likert Scale	Strongly Disagree	Disagree	Neither Agree / Disagree	Agree	Strongly Agree
Participant #7			P_O < ----	------- P_R	

Note: Comparison of each participant's attitude rating pre-training (P_R) and post-training (P_O). The arrow shown indicates the direction of change.

Following completion of the training regimen, four of the participants' attitudes changed while three participant attitudes remained the same. Three of the four participants that changed their attitudes, did so moving toward the disagreement side of the scale; this can be viewed as positive indication that the participants felt less "like a button-pusher than a pilot" with the GFD system compared to pre-training perceptions.

The final GFD Attitudinal Survey Statement #5 reflected the individual participants' attitude towards the general use of the GFD system during flight. Comparing participant responses pre-training (P_R) and post-training (P_O) for this statement showed very little change or movement in participants' attitudes about the Agree/ Strongly Agree range. Table 23 shows the before (P_R) and after (P_O) Likert scale ratings of the participants regarding their attitudes towards the general use of the GFD system during flight.

Table 23

Comparing Participant Attitudes Before and After Training – General Use of the GFD System During Flight (S#5)

S#5: *Advanced cockpit systems can get you into trouble as easily as they can get you out of trouble.*					
Likert Scale	Strongly Disagree	Disagree	Neither Agree / Disagree	Agree	Strongly Agree
Participant #1					P_R -- P_O
Participant #2				P_O < ----	------- P_R
Participant #3				P_R -- P_O	
Participant #4					P_R -- P_O
Participant #5				P_R ------	---- > P_O
Participant #6				P_R -- P_O	
Participant #7					P_R -- P_O

Note: Comparison of each participant's attitude rating pre-training (P_R) and post-training (P_O). The arrow shown indicates the direction of change.

Prior to starting training, participants all agreed or strongly agreed that a GFD system "can get you into trouble as easily as they can get you out of trouble" – for which is a common theme found in the literature of previous research. While two participants actually changed their attitudes, the net effect was nil for the group as a whole. It would appear all the participants entered and exited the training regimen with solid respect for the benefits the GFD system brings to the flight environment, but also strong respect for the potential for troubles with using the complicated GFD system.

Interview of Participants' Overall Individual Training Experience

Upon completing the final phase of the training regimen, the participants were given an interview questionnaire with questions regarding on their overall training experience. Questions focused on their training with specific regard to using Scenario-Based Training (SBT), how usable the GFD system was, comparisons of the GFD training systems, and time commitments, stress, and/or elation they may have experienced. Participants were requested to type their answers into the protocol form directly and submit the form digitally back to the researcher.

The digital responses of the participants were formatted for qualitative data analysis with NVivo. As with the CBT and FTD Flight Debriefs, the final training debrief questions served as a starting point for eliciting participants perceptions and attitudes toward their overall training experience as a result of participating in the study. The researcher again used the NVivo software to aid in organizing participant responses, coding the responses into common terms and groups, and building thematic maps from the coded groups.

The participants' responses were much more detailed and extensive given the time the participants had to craft and type their answers. This afforded the researcher opportunity to develop the richest of code and theme building, and the results are reflected in Figure 9 thematic map. The participants again provided consistent and similar information in their responses, in both positive and negative comments, and the themes that were mapped are varied yet quite visually telling. Figure 9 is a visual map of the themes that reflect the participants' perspectives with respect to the overwhelmingly reported positive scenario-based training experience on the GFD system.

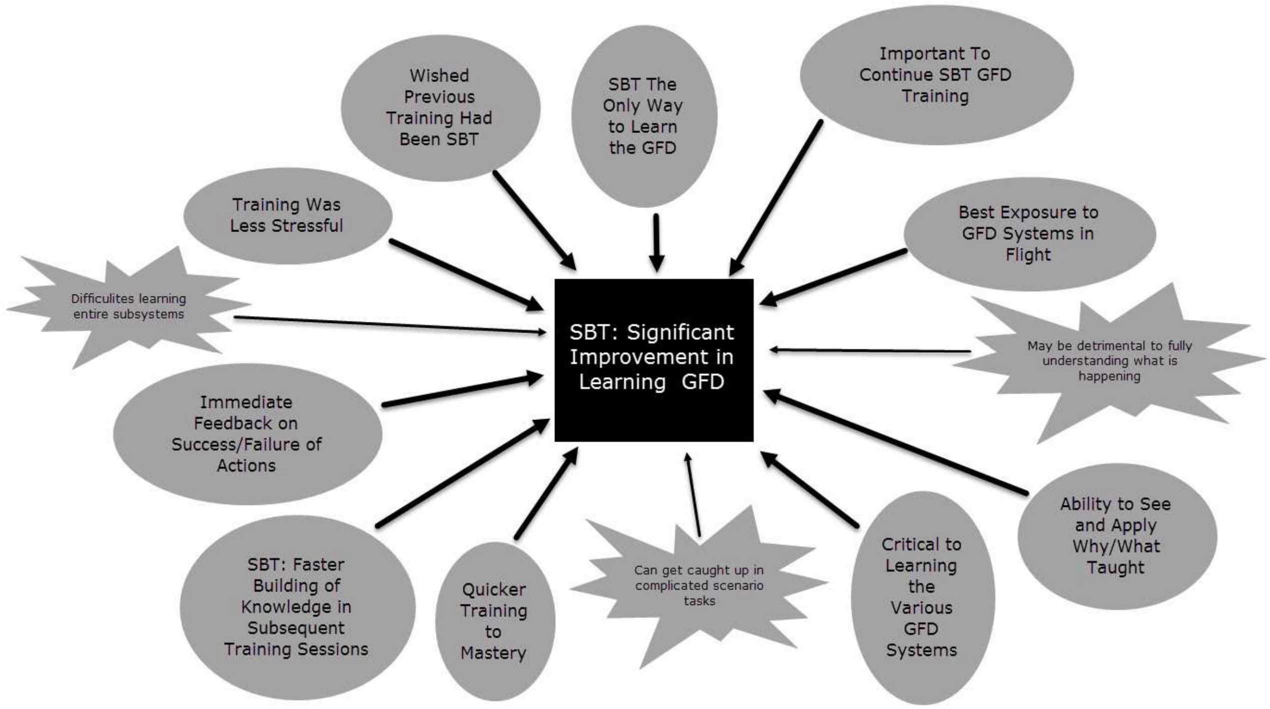

Figure 9. SBT: Significant Improvements in Learning the GFD System – Visual Map. Participant perceptions, negative and positive, that reflect their overwhelmingly positive training experience while learning the GFD system, as reported via the final training debrief questionnaire at the conclusion of the study.

In the visual map of the codes and themes, Figure 9 provides an overview of the participants' perspectives towards their training experiences using scenario-based training strategies in learning and mastering the GFD system. Summarizing the visual map, participants reported both positive and negative perceptions and attitudes with the scenario-based training on the FTD GFD training system, but the overarching theme was the significant improvements experienced in learning the GFD system using this training strategy. Of particular note was the increased themes positive in nature, and the corresponding reduction of negative-based themes the participants reported via their answers. As can be seen by the dominating large oval symbols and bold print, participants' predominantly reported that scenario-based training was a significant improvement in learning the GFD system in a number of ways. These include the constructive building of GFD system knowledge faster, the criticality of SBT to learning not only the various complex GFD subsystems, the importance of continuance in using this training strategy, and the ability to truly apply what has been taught in a less stressful and more meaningful way through SBT training. Again, in constructivist terms, these types of learning experiences are important to building higher order thinking and critical decision-making skills so important pilot training.

Again, negative codes and themes did emerge. However, they were considerably fewer in number compared to the positive themes uncovered. The negative themes primarily revolved around difficulties in learning and integrating the complex GFD subsystems, and the resultant lack of understanding of fully understanding what some of the GFD subsystems were doing. These negative themes, albeit important discoveries, are clearly resolvable with additional scenario-based training exercises, and for which all of the participants reported desire for extended training coursework and opportunities to help them mitigate these negative experiences.

Summary of Results

Throughout the training regimen, data were collected in a variety of formats, and subsequently analyzed. A combination of researcher observation field notes, demographic, attitudinal, and usability survey data, and focus group interview data were collected over the two-day training regimen. Seven participants completed the training regimen, and all participants took the demographic and usability surveys, as well as participating in the focus group interviews. All participants successfully completed all phases of the training.

Participant Demographics and GFD Flight Experience

Participants in the study were comprised of juniors or seniors in their academic year of a Bachelor of Science degree program, with six of the seven participants majoring in the professional pilot/flight officer program. All were pursuing commercial flight careers in the aviation industry. Of the total group, five participants were licensed private pilots currently working towards their instrument rating or commercial license, and this group of pilots had logged an average of approximately 110 flight hours each. These participants were the "instrument pilots" subgroup. The sixth and seventh participants had acquired private and commercial pilot licensures, and both hold current instrument and multi-engine ratings. These participants had logged an average of 395 total flight hours each. One of these two was also working towards a certified flight instructor license (CFI), while the other one had recently achieved certified flight instructor licenses for both visual and instrument flight rules (CFI-I). All of the flight hours reported by participants for their certifications and ratings are found be consistent with FAA expectations and the university's aviation department extensive 35+ years of experience when acquiring such ratings and certificates.

All seven participants had little flight time experience in aircraft with GFD systems. No participant logged more than 30 total flight hours (visual plus instrument combined) in aircraft with GFD systems. Participants offered both positive and negative perceptions and comments regarding GFD systems. All of the participants reported excitement with the training opportunity to learn how to use GFD systems, and yet, concerns were offered of being intimidated in using the GFD system, learning the complexity of the GFD system, and need for better training to become more comfortable with using the GFD system. These perceptions of the participants were found to be consistent with the numerous studies cited in the literature review, including Casner (2008, 2009), DeMik et al. (2008), Kearns (2007, 2011) and Mitchell et al. (2009; 2010).

Participant Attitudes with GFD Systems – Pre- and Post-training

Participants expressed a variety of attitudes when responding to the GFD Attitudinal Survey, both before starting training and after completing training. The first two statements reflected attitudes with the technological complexity and sophistication of the GFD system. With respect to the first two statements, participants responded in concert with each other. Most did not agree that GFD systems technology had "gone too far", and there was strong agreement by all participants looking "forward to new kinds" of GFD systems. The participants held consistent on their attitudes for both statements in the pre- and post-training surveys. The training regimen did not appear to change participant attitudes on the technological complexity and sophistication of the GFD system.

When responding to the third and fourth statements regarding how the GFD system relates to their individual piloting skills, the attitudes expressed were quite varied. Pre-training attitudes were approximately split 60-40 among the participants between disagreement and agreement scales regarding how well the GFD system "made use of" basic piloting skills, and whether the GFD system made participants "feel more like a button-pusher". Post-training attitudes, however, did change. It would appear that training on the GFD system softened initial participants' attitudes of their confidence in their individual piloting skills, yet improved participants' attitudes towards engaged use of the GFD system.

The final statement reflected the positive-negative aspects of the general use of the GFD system during flight. Overwhelmingly, in the pre-training attitude survey, all participants agreed or strongly agreed that GFD systems “can get you into trouble as easily as they can get you out of trouble”. Nothing appeared to change in post-training attitudes as all participants again showed strong agreement with the statement. Based on the researcher’s recorded observations during the actual flights on the FTD GFD systems, participants saw first-hand both how GFD systems can be a valuable asset, but also requires training to be used effectively. The attitudes of the participants also reflected many of the perceptions and attitudes outlined by researchers such DeMik et al. (2008), Kearns (2011), and Mitchell et al. (2009) previously cited in the literature review.

Researcher Field Notes Observation – CBT and FTD Training Phases

The researcher took copious notes on the training environment and setting for both the CBT and FTD training phases. In addition to monitoring the training settings, the researcher was interested in recording the participants’ comments and behavior while completing the training sessions. Both CBT and FTD training settings were subdued. All participants attended each GFD training session. Participants asked numerous types of questions, and made comments throughout both the training sessions. Participants seemed fully immersed in their CBT GFD training work, and were engaged in asking questions and commenting aloud about their training experience. It was apparent the participants were trying to implement procedures and processes learned in the traditional lecture training sessions and hands-on practice.

The researcher’s field notes observing the participants prepare, setup, and fly the scenario-based flights on the flight training devices (FTDs) provided triangulation evidence much in the same way the CBT-based flight tasks observations. These field note observations provided a convenient way to watch over each participant's flight without interfering or interjecting while the participant concentrated on completing the flight scenario plan as required. The execution of the SBT flights on the FTD GFD systems occurred with no issues or disruptions. The researcher noted a level of confidence as most participants went about their business with what could be described as "abundant" confidence and an upbeat attitude of knowing what they were doing. All the participants talked aloud as they worked through the SBT flights and most seemed quite focused working with the GFD system. The researcher noted with approval the participants even reverted to their prior training going back to the basics of flying the aircraft – a pilot behavior heavily drilled and emphasized by CFIs when dealing with complex aviation equipment. Overall, based on the researcher's observation field notes, the general tenor of the CBT and FTD training sessions and SBT flights were all very positive.

CBT and FTD Training Experience Interviews

The researcher held focus group interviews immediately following the participants' completion of the usability surveys for both the CBT and FTD training phases. Identified as Flight Debriefs, the participants assembled in a 12-person conference room away from the training laboratories. The responses of the participants were transcribed verbatim into MS Word directly from the Flight Debrief Protocol form. The NVivo software program was used to aid the researcher in analyzing the participants' responses to the flight debriefs completed in the focus group interviews. The researcher organized participant responses, coded the responses into common terms and groups, and built thematic maps from the coded groups. The codes and themes helped the researcher to see patterns through the building of visual maps.

The participants' responses from the CBT GFD training focus group interview were made as primarily very short phrases. These responses made for limited coding and theme building, albeit the participants provided consistent and similar information in their responses regarding both positive and negative comments about the CBT training experience. Participants overwhelmingly reported the training was positive and had lasting impact on their knowledge and learning of the GFD system, and transferring over to their training with the FTD GFD system. Positive themes uncovered included the training was good for refreshing past training, provided lots of opportunity to practice, and the training materials directly applied to more thorough learning of the multiple GFD systems. Negative codes and themes were less significant, albeit similar and consistent among the participants. Negative themes included problems with the CBT systems input interfaces (primarily mouse and keyboard) and cumbersome menus making it difficult to manipulate the program, and poor user error recovery in the software when entry mistakes were made.

A noticeable change was observed during the FTD GFD focus group interviews. The participants became more comfortable with the focus group interview format, and their responses for this flight debrief were in the form of more detailed phrases, compared to their somewhat limited responses during the CBT focus group interview. The enriched detail made for richer coding and theme building as reflected in the visual map (Figure 8). Again, participants responses, both positive and negative, were found to be consistent and similar throughout the group.

Participants' predominantly reported the FTD GFD system as important in fulfilling hands-on training, in providing immediate feedback (success/failure) on GFD behavior, and in developing the demands of focus and concentration when dealing with the integrated GFD subsystem, but the overarching theme was the FTD GFD training was the best training experience received in their aviation education to date.

Participants consistently noted that they needed more SBT training on GFD systems to work through undesirable issues. Negative responses and comments revolved around issues with attention diversion that arose using the complicated GFD and the related complexity of the various menus, buttons, and switches prevalent in GFD system. They reported having gaps in their knowledge of the functions and integration of the various GFD subsystems, but felt that additional SBT training would help them resolve the knowledge gaps.

CBT and FTD Usability Surveys Analysis

The usability surveys conducted on the CBT and FTD GFD training systems were accomplished using the Systems Usability Scale (SUS) survey. The SUS survey is a Likert-type scale based survey. The participants completed the SUS survey following the training sessions on the CBT GFD and the FTD GFD training systems.

Both the CBT and FTD surveys scored better than 0.70 (Cronbach's alpha of reliability) with 0.762 and 0.851 respectively. These results indicated both sets of surveys were rated good to quite good for internal reliability and both survey sets passed the error checking process for validity. This allowed for direct comparison of CBT and FTD survey scores throughout the analysis. The researcher converted scores to percentile ranks to be able to apply descriptive ratings (Marginal/Poor, Acceptable, Average, Good, Best) consistent with Sauro's (2011) advice on "best practices" for SUS survey analyses. Both the CBT GFD (59.6) and FTD GFD (52.9) systems mean SUS scores earned a rating on Sauro's descriptive scale of "Acceptable". Mean scores were also calculated for the subscales of usability and learnability.

Here the systems rated much differently. While the CBT GFD system's mean usability score improved (64.7), it still rated "Acceptable" albeit being very near to scale margin for "Average" (65). The FTD GFD system mean usability SUS score also improved but slightly (59.4) and retained an "Acceptable" rating. Ratings of "Marginal/Poor" were given for the learnability mean scores for both the CBT GFD (39.3) and FTD GFD (26.8) systems, and this was a bit surprising. As can be seen from these scores the more complicated and complex FTD GFD system had lower overall scores for both subscale items and this is underscored in reviewing the individual participant scores.

Individual participant scores were analyzed for their overall SUS scoring, as well as, the subscale scoring of usability and learnability. The CBT GFD system was generally rated as "Average" but two participants scored it low and thus the mean overall score dropped its rating to "Acceptable" as noted above. Comparatively, the FTD GFD ratings by the participants were even lower across the scoring. Sixty percent of the participants rated the FTD GFD systems overall use as Marginal/Poor and forty percent rated it as "Acceptable-to-Average". Participants rated the CBT GFD system's usability similarly with slightly higher scores, but not enough to improve its descriptive rating. Interestingly, participant scoring was quite varied for the FTD GFD system's usability rating; participants gave ratings in all five rating scales of "Best", "Good", "Average", "Acceptable", and "Marginal/Poor". The usability ratings for the FTD GFD system was the one rating with the least consensus among the participants. Participants scored the CBT GFD system's learnability so low (five out of seven, or 70%) that only a rating of

“Marginal/Poor” could be attained. The FTD GFD system’s learnability rating was even more dismal. Total consensus was achieved as all seven participants rated it “Marginal/Poor”.

SBT Flights – Duration Analysis

The added benefit of the data captured by the CFIs during the SBT FTD flights was observed immediately. The researcher analyzed the various SBT flight segments for consistency with expected behavior and execution. Flight segment legs were generally within expected times. Only the FTD setup and prep, and final aircraft check segments varied quite a bit between participants. These two items are generally individualistically driven and variances are reasonable and expected. The mean times observed showed there was consistency and quality of training the participants in the group had individually received. Also observed was the programmatic planning of the SBT flights in establishing a flight scenario that was a solid baseline from which additional comparisons could be made.

Each flight plan segment was time stamped to reflect the flight plan segments (FTD flight scenario start time, departure clearance request, take-off clearance request, air traffic control - emergency declaration, and landing time). Most of the participants were similar in their time spent to complete the various flight segments. The mean times for flight segments dealing with the aircraft inflight (e.g. takeoff to cruise, emergency declaration, approached in to the airfield, total time in flight, etc.) were all within expected bounds for the SBT flight as scheduled. For example, time in flight until requesting to return to airport (emergency declarations) averaged about 19 minutes, and total flight time was approximately 50-60 minutes in duration.

The researcher concluded the participant group SBT flights reflect what a real world small GA commercial flight using the GFD system would present in such a situation. Furthermore, the researcher confidently concludes all the participants experienced essentially the same flight scenario, and perspectives and opinions discussed in the findings sections accurately reflect their experience with the GFD training system used in the actual scenario-based flight plan. Each of the flights were flown according to a typical flight plan as would be filed with the FAA; this also insured the scenario-based flights stayed relatively on schedule as would occur in the real world.

Final Overall Training Experience Interview

Upon completing the final phase of the training regimen, the participants were given an interview questionnaire with questions regarding their overall training experience. Questions focused on their training with specific regard to using Scenario-Based Training (SBT), how usable the GFD system was, comparisons of the GFD training systems, and time commitments, stress, and/or elation they may have experienced. Participants were requested to type their answers into the protocol form directly and submit the form digitally back to the researcher.

The digital responses of the participants were formatted for qualitative data analysis with NVivo. The participants' responses were much more detailed and extensive given the extra time the participants had to craft and type their answers. This afforded the researcher opportunity to develop the richest of code and theme building, and the results can be seen in the Figure 9 thematic map. Again, great consistency and similarity of information was found in their typewritten responses, both in positive and negative comments.

Of particular note was the increased number of themes quite positive in nature, and the corresponding reduction of negative-based themes the participants reported via their responses. Participants' reported that scenario-based training was a significant improvement in learning the GFD system in a number of ways. These included building knowledge of GFD systems faster, the importance of SBT in learning not only the various complex GFD subsystems, but in the continuance in using this training strategy for future knowledge development. Participants remarked on their ability to truly apply what has been taught in a less stressful and more meaningful way through SBT training.

Negative codes and themes did emerge, but were considerably fewer in number. Negative themes primarily revolved around difficulties in learning and integrating the complex GFD subsystems, and the resultant lack of understanding of fully understanding what some of the GFD subsystems were doing. These negative themes, albeit important discoveries, were identified by the participants as resolvable with additional scenario-based training exercises and extended SBT training coursework.

Chapter 5

Conclusions, Implications, Recommendations, and Summary

Introduction

The results of the study reveal interesting and valuable information for the future training of pilots on GFD systems. Conclusions are discussed with respect to the success of the study in reaching its objectives. Strengths and weaknesses of the study are explored and limitations of the study are also addressed. Implications for future pilot training on GFD systems are discussed and include the potential impact the results of the study have on professional flight knowledge and instructional practices. Future areas of research are outlined and suggestions for improving future studies are offered.

Conclusions

As a member of the pilot training community, the researcher was aware of various issues in the surrounding geographical area with the training of GA pilots on GFD systems commonly found in today's GA flight training aircraft. After an extensive review of published literature, it was clear the observed issues were not restricted to the researcher's regional pilot training environment. The researcher presented extensive literature documenting known concerns and issues in military and commercial airline domains in the learning and mastery of the complex technology in aircraft with advanced flight deck and GFD systems. It was also discovered that problems experienced in those domains were similar to issues being experienced in the general domain of GA pilot training, and very similar to the researcher's lived experiences of difficulties encountered by pilots training on GFD systems in his training facilities. The researcher observed local training issues that included inadequate training manuals, textbooks, and training content – similar issues were reported by Casner (2008), Harris (2012), and Mitchell, et al. (2010). The researcher experienced too-limited training commitments and training time and opportunities, which were similarly reported by Hahn (2012), Kearns (2011) and Mitchell, et al. (2009) in their studies. The researcher monitored repeated complaints and concerns of local pilots' dissatisfaction with their training experiences on GFD systems. These issues were also reported by authors Casner (2008, 2009), Hahn (2102), and Kearns (2007, 2011) in their various reports on existing research. The issues and concerns uncovered were summarized in the general problem statement in Chapter 1 as a lack of effective training and learning methods for flight instructors and pilots in mastering the GA glass flight deck system. The goals of this study were established to investigate if:

- the learning and training process for GA pilots on GA aircraft glass flight deck systems is improved by implementing scenario-based training approaches,
- the quality of the pilots' learnability and usability experience through scenario-based training approaches with GA aircraft GFD systems improved their satisfaction with, perceptions of, and attitudes toward training experiences on GA glass flight deck systems, and,
- improvements in the quality of the training experience of pilots resulted through scenario-based training approaches, would there be improvement in pilot perceptions and attitudes regarding their overall use of and reliance on GA aircraft glass flight deck systems

Derived from the goals of the study, the following research questions were established, and addressed.

RQ#1: To what extent does the quality of user learning and training experiences improve by utilizing a scenario-based training approach to the use of glass flight deck systems by pilots?

With respect to RQ#1, the participants overwhelming related their learning and training experience as positive, and that learning the GFD system was greatly improved through the use of the scenario-based training approach. The use of scenario-based training was reported by Craig (2009), Kearns (2011), and Summers et al. (2007) as a plausible way to achieve active learning and knowledge construction, and for which the FAA's (2004, 2006) FITS program was a key motivator in improving pilot training in general. This motivation was reflected in participants' interview responses regarding their overall training experience. Participants' responses also emphasized the benefits in learning key GFD system concepts via the scenario-based approach use in this study.

Positive sentiments and desires for more SBT training was found throughout all the types of data collected. Well documented in the researcher's field note observations of participant comments and attitudes, these results were captured in the participants CBT, FTD, and Final Training debrief statements, and were reflected throughout the GFD Attitudinal Surveys the participants completed. Statements documented include "scenario training is the only way to learn ...", "I wish I had been given this kind of SBT experience on the advanced cockpit before", "the scenario training really helped me to understand how the different parts of the glass flight deck went together. I did not get that in previous training…", and "the second day I felt more confident with how to enter a flight plan and set up autopilot, having that …made the situation less stressful…”. Interestingly, many verbal comments were made following the completion of the training regimen, expressing interest in additional training. Inquiries included if the researcher was going to do another SBT study, asking if more training would be offered that they could take, and if there were going to be any pilot training courses using the SBT approach in which the participants could enroll.

RQ#2: To what extent does the quality of the learnability and usability experience of pilots utilizing a scenario-based training approach improve their satisfaction with, and perceptions and attitudes of their use of and reliance on glass flight deck systems?

Throughout the literature review, issues and concerns with learning GFD systems were found. For example, Casner (2008, 2009), Hanh (2012), and Mitchell et al. (2010) pointed out the difficulties with learning the complex GFD system led to various pilot reports of dissatisfaction and limited use by pilots. In contrast, however, numerous studies also reported pilots interviewed were overwhelmingly happy and excited to have improvements in information, situational awareness, and flight capabilities available and accessible with GFD systems in flight, even given the learnability and user satisfaction issues (Demik et al., 2008; Hahn, 2012; Kearns, 2007; Mitchell et al., 2009, 2010).

Answers to RQ #2 were very interesting, and quite varied. While there was considerable data noting the participants all had positive attitudes and perceptions of the GFD system, much of the usability survey data reflected participant poor ratings on the learnability and usability of the complex GFD system. However, the majority of the participants also pointed that although learnability and user satisfaction issues clearly existed, the scenario-based training helped them to better learn the GFD system and spurred them on to seek more training in order to fully explore and learn the GFD system in its entirety.

Similar issues were also discovered in this study via the participants' surveys on usability and learnability with the GFD trainings systems used. Participants reported via the usability surveys issues with learning both the CBT and FTD GFD systems, but similarly reported in the attitudinal surveys of their desire to fully learn to use the GFD systems, the importance of it to their future careers as pilots, and their excitement in learning and using the extensive capabilities of the GFD systems. While there was considerable comment regarding the difficulty to learn the complex GFD system, the participants emphasized the importance to master the GFD system as paramount to careers and in improving their pilot skills. Participant statements included "I'm excited to learn how to better use the …system …", "I view learning/using glass flight deck systems are one of the most important skills a modern pilot would need to attain so become fully competent in future systems", "I felt that having another full class …on the system really helped me fully understand some of the small things I had missed in my previous experience", and "I (still) believe that the GFD systems can be a great asset, but… can also be detrimental if you do not understand what is happening …and you get caught up in the programming…".

Of particular note, having completed the entire training regimen, the participants' focus group interview and the final training debrief data were replete comments and responses that the use of the SBT approach to learning the GFD system had helped overcome some issues of learnability, albeit issues still exist. The participants were in consensus that they were motivated to learn more about the GFD system using a scenario-based approach, and that their satisfaction with the training on the GFD system was improved.

RQ#3: What, if any, are additional instructional designs improvements in glass flight deck training suggested or found through implementing the changes in the training methodology as proposed?

The study was designed to achieve the specific goals and attempt to uncover answers to all the research questions. It is this research question #3 however, that is at the center of the researcher's desire to understand what changes in current training approaches and instructional design improvements can be made. From the results of the study, core changes in instructional design strategies should be made that will result in improvements to current GFD systems training. The traditional lecture combined with CBT part task training and followed by scenario-based training is an excellent example of successful changes in instructional design as applied in this study. And this would be in concert with Craig (2009), Kearns (2011), and Mills (2012) suggestions that an overall training process should move from development of declarative knowledge to procedural knowledge and then applied knowledge through a series of knowledge construction processes so knowledge transfer to real-world situations is achieved. Key to the core changes used in this study include the integration of scenario-based training events, in order to improve transfer knowledge acquired via traditional GFD training methods being used. Improving phased-use of CBT on GFD systems should be scrutinized deeper for greater benefits, and additional instructional design efforts should be completed in integrating and following with expanded and extensive training in FTD-based GFD systems in a more rigorous format.

SBT Events Integration

The primary result of the data uncovered in answering RQ#3, is the importance of integrating SBT strategies into existing training curriculum. This integration will necessitate a rewriting of the current training methods and materials to include scenario-based training events for each of the GFD subsystems and for the overall GFD systems training process. The literature review noted numerous researchers and authors who reported on significant problems using glass flight decks when training new pilots due to learnability problems introduced by the extensive complexity and sophistication of glass flight decks (Baxter et al., 2007; Casner, 2008, 2009; DeMik et al., 2008; Mitchell et al., 2010). This study has shown that integrated scenario-based training had a positive impact on the participants learning of the GFD system and their overall training experience. Therefore, efforts need to be made to incorporate scenario training events that address the complexity of the GFD subsystems so problems with learnability of the complicated GFD systems interface can be managed at least, mitigated at best. Entire scenarios appropriate for the knowledge required for mastery of the GFD system should be developed and integration of the scenario training events should be carefully reviewed for continuity of training flow as was done for this study. Teaching faculty (CFIs) should be included in the development process to provide testing, feedback, and consistency in learning content.

Rigorous Phased Use of CBT and FTD-based GFD Systems

Exposed in the execution of the study's training regimen was the value and benefit the participants received by employing a "traditional lecture to-CBT flight exercises to-FTD flight" strategy. This reflects what Hahn (2012), Harris (2008), and Kearns (2011) called a "balanced approach" in developing GFD flight, critical thinking, and decision-making skills. Participants related better learning and use of the GFD systems, especially when implemented in flying actual flight tasks and flight scenarios. Clearly the strategies applied in the study produced positive results. However, also exposed during the study, were certain training aspects with the CBT and

FTD GFD systems that require a rethinking and tweaking, including the amount of time each training system is used and the extent of scenario training that can be effectively covered with each system. Consideration for a more structured step through learning process for properly mastering the various GFD systems is advised. The constraints on training time for the study as executed, pointed out areas where the training segments can be improved and extended so the pilots training is more complete. In addition to the strengths of the study results, some weakness and limitations were also uncovered.

Strengths, Weaknesses, and Limitations of the Study

The study proved to be a considerable undertaking. Much data were collected and as such the results were valuable and beneficial in many ways. The diversity and mix of participants in this study were strengths, as was the use of a case study approach in attempting to meet the study goals and answer the study research questions. The training of GA pilots attending the aviation university program showed that participants experience many of the same positive yet cautious perceptions and attitudes towards learning and using GFD systems as was uncovered in the literature review. Scenario-based flight training also proved to have significant value in not only improving the participants use and learning of GFD systems, but also in improving participant perceptions and attitudes of their overall training experiences. The results of the study also exposed new instructional design improvements that can be made in an area of pilot training that is difficult and demanding to master. This is also the first known study to integrate SBT flight scenarios into GFD systems training processes, and so it can be considered potentially breaking new training ground.

There are some weaknesses and limitations to this study. As this study is assumed to be the first known approach to using scenario-based training for learning GFD systems, there were not any previous studies to model, nor data collection efforts and results to consider improving upon. One possible weakness is the vested nature the researcher had in completing the study in his own institution and driven by his own teaching and training experiences and biases. Much was done to combat this potential weakness, including bracketing, member-checking, utilizing a wide variety of data collection strategies, and undertaking considerable data triangulation. It could be suggested that a study with only seven participants is a limitation. However, considering this is a case study approach, given the size or number of participants, while a limitation, the results are not intended to be generalized to the larger population of all pilots training on GFD systems. Even with this small number of participants though, given the extensive data collection and the representativeness of the participant group to their overall fellow students and peers in training, the results do potentially transfer to those pilots who are in the university aviation training taking similar coursework.

Implications

Through the literature review, it was discovered that legacy training approaches are often not perceived as successful as need be, and due to the complexity of the GFD system, traditional training approaches used for training on older non-GFD GA aircraft are not as effective as needed for modern day GFD systems in GA aircraft (Casner, 2008, 2009; Hahn, 2012; Kearns, 2011; Mitchel et al., 2009, 2010). There are a number of areas the results of this study potentially influence the domain of pilot training on GFD systems, pilot knowledge, and professional practice. There are also potential benefits on using the phased training and integrating scenario-based training methods into the process of constructing knowledge and the mastering a critical network of digital based flight and navigation subsystems found in the GFD system.

There are also contributions to the current day knowledge of training pilots on GFD systems. Recognizing that while GFD systems are highly complex and difficult to master, with appropriate changes in instructional design approaches, the knowledge of *how to train*, as well as the *construction of knowledge during training* can both be improved (Craig, 2009, Hahn, 2012; Kearns, 2011; Mills, 2012). Moreover, this has an impact on those pilots who are certified flight instructors as well. Professional practice sees direct benefits as result of this study, allowing professional flight instructors to improve their teaching processes and training materials in a far-reaching and important way.

There are implications for future research as well. While the instructional design process was modified in this research study with success, more investigation should be done to improve instructional designs around implementing scenario-based training approaches, in both the CBT laboratories, as well as the flight simulation laboratories (Hahn, 2012; Harris, 2008; Kearns, 2011; Mills, 2012). Additional research should be done to improve the process of integrating and using both the CBT and FTD GFD training systems more effectively into the overall traditional training curriculum and materials.

More rigorous and detailed usability research should be done on the usability and learnability of the CBT trainer software with the goal of getting the manufacturer to “buy-in” and improve the actual CBT GFD trainer itself. Similarly, more rigorous and detailed usability research should be done on the usability and learnability of the FTD GFD subsystems in order to understand which subsystems require more time to master. Consideration should be made for possibly “flipping” the curriculum, having pilots complete the traditional textbook and lecture training online on their own time, so more time can be spent during laboratory class time with hands-on on the CBT and FTD GFD training systems (Craig, 2009; Hahn, 2010; Summers et al., 2007).

Future Research Recommendations

Future areas for research have been identified from the results of this study. Additional research should be done to improve upon the instructional designs involved in implementing scenario-based training approaches throughout the entirety of GFD systems training. While the instructional design changes made in this study are a positive start, additional improvements can likely be achieved. This should include research not only when, how, and how much scenario-based flight training should be used, but also, if SBT may be useful in teaching individualized flight tasks replacing or supplementing traditionally taught flight repetitive task sequences. Research should also be completed to investigate the potential benefits of scenario-based training on CBT GFD systems, as well as how to better integrate scenario-based flight training in the actual flight laboratories using the cockpit identical GFD systems used in the FTD. This aspect of research may even lead to new approaches to GFD training that can be transferred out the actual live aircraft where real-world, live training actually takes place.

Usability and learnability were important aspects of this study and there is additional research that should be done here as well. While the SUS survey was a solid survey instrument for evaluating participants’ perceptions on the usability and learnability of GFD systems, the low ratings of the participants with the GFD training systems signals more work need be done improving overall GFD systems’ usability. This may translate into changes in the how the CBT

GFD software operates, to suggested design improvements to the manufacturer of the actual GFD systems used in GA aircraft.

It should be reiterated that the GFD training system is a considerably more complicated system made up of multiple complex subsystems, and have functional operation and capabilities well beyond many most traditional system interfaces benchmarks tested with the SUS. It is important to point out that the limited availability of other such highly complex standard systems SUS scoring did not allow better “systems to systems interface” comparisons to be made. It would be additionally important to expand research on the usability and learnability of the GFD systems in general, to include multiple manufacturers GFD systems. Comparisons between competing manufacturers of GFD systems may help to identify “best practices” or “best implementations” of the various but similar systems interfaces used. This also applies to software driven CBT GFD training systems. More valuable and informing usability comparisons are possible if the CBT GFD training system used in this study were, in future studies, compared to other similar GFD training systems from other software developers or vendors. Additionally, comparative data collected over time from multiple SUSs on the same GFD training system may also be more informative.

Changes in professional practice are recommended as well. The success with the use of scenario-based training in learning and using GFD systems was immediately recognized upon completion of the phased training program. Within days of completing the training regimen, the certified flight instructors participating in the flight scenarios in the flight training laboratories commented their experience with instruction of pilots of GFD systems was radically different than they expected. Indeed, the senior most CFI-I (the aviation university’s Chief Ground

Instructor, and a CFI-I at a local airfield's pilot training school) noted that he had already begun to rework his current curriculum and training to implement more scenario-based CBT and FTD flight training midway in the semester. He has continued making curriculum changes and improvements based on the study's results, as of this time. As the aviation department's chief instructor, he is responsible for reviewing existing faculty training approaches and making recommendations for training strategies, standards, and rigor for all flight instructors on staff. His interest in changing, improving, and implementing scenario-based into the curriculum currently in place has generated numerous discussions on future research studies by several in the department. Several of these research studies are projected to be completed by the staff of expert faculty instructors and staff he oversees.

Summary

Over the past several decades manufacturers of aircraft have increased the level of computer-based technology used in military, commercial passenger, and GA aircraft resulting in better avionics, navigation, and aircraft performance systems (Casner, 2008, 2009; Mitchell, et al., 2009, 2010; Shetty & Hansman, 2012). One direct result of these technology improvements is the additional training required for pilots to learn and master the sophisticated flight decks. GA aircraft pilots generally welcome new GFD technologies, however, traditional training methods for pilots on legacy flight decks are lacking due to the complexity and sophistication of the various GFD subsystems.

Training on GA aircraft with glass flight deck systems is widely varied, with limited standardization, and almost no formal training requirements in place. Extensive literature exists that documents the various learning and training challenges presented with GFD systems in technically advanced aircraft. Inadequate or incomplete training manuals and CBT programs, lack of standardized training curriculum, flight instructor changes, and limited analog-to-glass transition training materials are just a few of the challenging areas. New training methods are needed to address the new technological components, the incredible density of information available, and the variability of flight deck configurations.

The problem is the lack of effective training and learning methods for pilots in GA aircraft for mastering glass flight deck systems. The researcher investigated one possible training approach (scenario-based training – SBT) that may address some of these training challenges. The goals of the study included seeking improvements for pilots in the quality of their training experiences, their learnability experiences, and their resulting knowledge of the use and application of glass flight deck systems. The researcher sought to address research questions regarding the extent of improvement in the overall quality of pilot training experience and the extent of improvement in the pilot's learnability experience with the use of SBT strategies. It also sought to address what, if any, instructional design improvements might be uncovered or suggested due to implementation of the SBT training strategies. The researcher also looked at the usability of glass flight deck systems with respect to pilot learning and training experiences. The usability attributes of learnability and usability (user satisfaction) were measured with a standardized systems usability survey (SUS).

Scenario-based training emphasizes real-world oriented training opportunities for the flight instructor and pilot to learn and master aviation skills necessary to support the aviation training requirements of modern GA pilots, and in ways that encourage and instill practical application of knowledge and skills learned. Based on examples of flight situations and environments that pilots will experience in the real world, proponents of scenario-based training tout the improvement of higher order critical thinking and decision-making skills through realistic practice of the tasks and flight skills used in real-world situations (Clark, 2003; Kearns, 2011; Mills, 2012; Saus et al., 2006).

The researcher designed the study as a single case study using an embedded case design. Exploratory and descriptive methodologies were used to investigate the use scenario-based training on GA glass flight decks at a Midwestern aviation university. Using an SBT approach, a mix of training strategies was used. These strategies included traditional textbook material and classroom lectures, practice of flight tasks and scenarios in a CBT environment, and application and demonstration of mastery of entire flights in flight simulation devices. Various data collection strategies were completed at each phase of training. Using the embedded case study format, a qualitative research design was executed using the primary participant group to seek answers to the research questions and to determine if the goals of the study can be met with the instructional design changes in the training and learning procedures identified.

This study is relevant as the review of literature indicated that although pilots have positive perceptions and attitudes on the extent and use of glass flight deck technology in GA training aircraft, they also have concerns regarding learning and mastery of the complex and extensive capabilities of GA glass flight deck systems (Casner, 2008, 2009; Hahn, 2012; Kearns, 2011; Mitchell et al., 2009, 2010). It is also significant in that the findings contribute to a better understanding of best training practices and strategies for pilots as they add the role of "systems manager" to their overall pilot responsibilities.

Two participant groups were used. Tenured aviation faculty and staff CFIs comprised one group and delivered the training sessions to the participant group. The primary participants of the study were the second group, and are pilots currently training for instrument pilot and certified flight instructor privileges. All participants were screened to meet a strict pilot profile based on past training, current certifications, and currency of flight experience. All pilot learning and training took place in aviation classrooms and laboratories on the Midwestern aviation university.

As the primary aim of the study was to better understand pilot perceptions and attitudes throughout SBT training sessions on GA glass flight deck systems, a structured and programmatic set of training phases was well defined and followed. The participants were taken through both a pre- and post- training phase and two extensive and distinct phases of training involving traditional textbook and classroom lectures, interactive CBT partial task flight training on flight training devices, and complete flight scenarios on flight simulators.

Throughout the training regimen, data were collected in a variety of formats (e.g. researcher observation field notes, demographic, attitudinal, and usability survey data, and focus group interview data), and subsequently analyzed. The data were collected over the two-day training regimen. Seven participants completed the training regimen, and all participants contributed to each of the data collection strategies. All participants were able to successfully complete all phases of the training. The qualitative data were analyzed for codes and themes and triangulated to confirm validity. Survey data collected were quantitative in nature, and were statistically analyzed. Limited scenario flight training data were also captured that were statistically analyzed.

Participants provided profile demographic information that included items such as current academic and pilot statuses, number and type of flight hours logged, and pilot licenses and certifications held. The researcher determined the participants were consistent with the type and experiential level desired for the study and met the traditional and legacy criteria established by the FAA over several decades for training on GFD systems. Participants were also asked about the extent of their experience using GFD systems and data acquired from the attitudinal surveys indicated a strong desire and belief in the training on GFD systems, yet expressed reservations about the difficulties of learning a complex system that could create problems as much as improve the safety of flying and pilot flight skills.

Researcher field notes from observing the training phases provided complementary data in a variety of ways. Throughout the traditional lecture and CBT GFD training sessions, participants were engaged and immersed in the training sessions on the GFD system, were quick to ask questions, clarify explanations, and showed a committed effort to learn and master the GFD system. The participants completed the CBT training session by completing a systems usability survey (SUS) intended to capture their perceptions on the usability and learnability of the CBT GFD training system. They also participated in a focus group interview concluding the first phase of training. Overall, the researcher concluded the training sessions and CBT flight exercises as very positive and successful training experience based on participant comments, efforts, and participation.

The CBT GFD system usability survey and the focus group interview revealed interesting data. The survey data scored a high Cronbach's alpha (0.762) and was determined to have high internal reliability. Participant mean scores were calculated and compared against each other.

Scores were also compared against global system interface data and specific industry systems interface data collected and published over years of SUS survey work. Usability and learnability sub scores were calculated for comparison as well. Although participants' scores varied somewhat, overall, the participants rated the CBT GFD system as "Acceptable" for usability and "Marginal/Poor" for learnability. When compared to global and industry specific system interface datasets, the CBT GFD system showed similar scoring as found with the participants' perspectives, with only approximately 35-40% of the time scoring higher that global and industry-specific system interfaces. This too would equate to a rating of "Acceptable" to "Marginal/Poor". Of note, learnability scores – how difficult the system is to learn during first-time use – were consistently lower across all comparisons, which in turn lowered overall usability mean score calculations.

Focus group interviews of the participants' experiences with the CBT GFD training system showed overall positive experiences with the learning process. Some cited using the CBT GFD training was good exposure to learn/refresh on using the GFD system and to be able to practice what was presented in lecture and training materials. There was consensus however that manipulation of the CBT GFD system was cumbersome with some noting use of the mouse was imprecise, menus systems (GFD chapters/pages) seemed inconsistent, and recovery from mistakes was poor. These types of themes tie back to similar participant perspectives identified and scored on the CBT usability surveys and as repeated during the final training debrief.

The researcher also recorded field notes during observations of the FTD scenario-based flights. Once again, the participants were totally engaged and immersed in completing the training exercise. All participants successfully completed the flight scenario and everyone was talkative and expressive about the training exercise. The general observation was the FTD GFD flight scenario was a positive and valuable training experience. Early on during observation of the FTD GFD flight scenario, the researcher realized additional data were being captured due to the strict flight plan and the scripted CFI participation for the flight scenario. Following completion of the flights, analysis of these data rendered valuable information in the format of time stamps and flight duration data for each segment or leg of the flight plan.

The duration and time stamp data collected for each of the participant flight scenarios revealed the flight plans flown by all the participants were relatively consistent in execution, and completion. Each of the participants' efforts reflected GFD systems training skills acquired in the previous training sessions, and the flight plans were executed in fashion similar to what would be expected in real world flights. Furthermore, the descriptive statistics showed that although there were some minor variances between participants and some flight segments, the participants as a whole performed exceedingly well in executing the flight plans representative of GA commercial flights. Other than a few reasonable GFD systems skills issues encountered by the participants, the FTD GFD flight scenario experience was reliable and constructive as a new instructional design approach to GFD systems learning and training experiences. Following the completion of the FTD GFD flight scenario, participants again rated the usability and learnability of the GFD training system and their ratings showed they experienced similar issues as when working with the CBT GFD system. Although the FTD GFD survey data scored a higher Cronbach's alpha (0.851) and was determined to have very high internal reliability, the SUS scoring was lower for both usability and learnability subscales, and participants' rated the FTD GFD much lower as a result.

The overall participant ratings of the FTD GFD training system were generally spilt down the middle with half scoring the FTD GFD as “Acceptable/Average” and the other half rating it as “Marginal/Poor”. However looking at the subscale scores, learnability across the board was rated considerably lower by all participants and this lowered the overall mean usability scores for the FTD GFD system substantially. Here again, it would appear that there is not only consensus among this study’s group of participants, but there also is quite a bit of similarity discovered through the literature review of previous surveys of GA pilots working with similar GFD systems. The FTD GFD system not only was rated poorly by participants, but was also found to be compare markedly lower against historical scores for other systems interfaces, with only 20-25% of the time scoring higher than global and industry-specific system interfaces compared, again.

Contrastingly, there was considerable praise by the participants during the focus group interview and in the final training debrief transcripts for training with the FTD GFD system. There were also strong and particularly positive sentiments for the use of scenario-based flight training on the GFD system. The focus group interview data reflected perceptions of importance of having hands-on-work with the FTD GFD system, and of the eye-opening aspects of both successes and failures in using the various complex GFD subsystems. Many positive statements of the focus demanded of the scenario-based flight and overarching comments regarding motivation to obtain more scenario-based training were common reports. Yet, there were cautionary comments in the focus group interview and the final training debrief regarding the need to work more with the actual FTD GFD system, to work out problems with attention diverting issues with the system, and not being familiar with the entire set of subsystems that comprise the FTD GFD system. Thematically, many of these comments can be tied back directly to the usability and learnability issues identified in the participant SUS ratings, and the GFD attitudinal surveys completed. These comparative and contrasting themes are also similarly found throughout this study's review of the literature.

Comparing the CBT GFD and FTD GFD training systems rendered important and distinct differences between them. The CBT GFD system received a markedly overall better usability rating by most of the participants. Comparatively, the FTD GFD system had lower SUS scores and ratings – a likely reflection of the considerable complexity of buttons, switches, and menus. Neither system rated very high for the learnability subscale scorings.

Attitudinal surveys were completed prior to the start of the training regimen and after the scenario-based flight plan was completed. Prior to the start of the training, attitudes and perceptions of the participants reflecting the technical sophistication of the GFD system were quite positive and most participants looked forward to new kinds of advanced cockpit systems. Regarding attitudes about pilot skills and the GFD system, there was small variance about the neither agree/disagree range on how much the participants felt the GFD system allowed them to use their pilot skills versus being turned into a button-pusher. Most leaned toward the neither agree/disagree, or toward disagreement, that their skills were underutilized or that they became button pushers. All participants felt that the positive benefits of GFD systems could just as easily turn detrimental in getting into and out of troubles while in flight.

Post training attitudes changed very little reflecting mostly a continuing overall desire to work with GFD systems, and appreciation for the benefits and importance of learning to use GFD systems fully, and the impact of GFD systems on individual pilots skills. Regarding the technical and sophistication of the GFD system, participants' attitudes changed only a bit reflecting a continued strong belief the flight deck has not gotten too technical, as well as a strong desire to see and work with new and advanced cockpit systems. Attitudes on the impact the GFD system has on pilot skills showed some consolidation about the neither agree/disagree scale, and some reported attitudes a bit more concerned about the lessening of pilot skills, while other participants' attitudes improved regarding their skills and their relationship to the GFD system. Finally, there was little to no change in attitudes of strong agreement of the GFD systems' ability during flight to create problems for pilots just as easily as getting the pilot out of trouble.

The analysis of the data revealed interesting and valuable information. Throughout most of the data collected, the participants were similar and consistent in their perceptions and attitudes regarding training on GFD systems. While there was the occasional instance of participants having opinions or issuing usability ratings that did not concur with the rest of the group, in general, there was considerable consensus in the group's perspectives and attitudes on using a scenario-based training approach, and towards the importance of using more scenario-based training for GFD systems learning. And there was considerable consensus that usability and learnability issues exist when training to learn and master GFD systems, for both CBT GFD systems and FTD GFD systems alike.

Final Comments

Over the past few decades pilots of all types have reported concerns with the difficulty of mastering advanced flight deck systems while at the same time lauding the technological improvements in avionics, navigation, and aircraft performance GFD systems provide. Inconsistencies in standardization of training methods and limited research on best practices for mastery of GFD systems have created a significant lack of proper and effective training and learning methods for mastering the GA glass flight deck system. GA pilots and flight instructors need improvements in training and learning methods for the proper use, integration, and application of all the subsystems that are integrated into the greater GFD system. Many of these same themes were echoed in the participants' perceptions of learning and mastering the GFD system.

Through the use of rigorous data collection and analysis methods, the researcher is confident the data show the participants (GA pilots) have a continued balance of positive attitudes about the use and benefit of GFD systems, while maintaining a healthy skepticism about the technical sophistication and limits of the GFD system. The participants also continue reflection on limits the legacy and traditional training methods have had on learning the GFD system, but also have shown a high regard and desire for more scenario-based flight training on GFD systems. The participants have pointed out concerns with existing usability and learnability issues with training on the GFD, but welcome continued advancement of technological sophistication of the GA flight deck. It is the contention of the researcher that this study, as executed, has addressed the goals of the study, and that the research questions as posed, have been answered. While future research in this area needs to be undertaken in a variety of areas, this study has successfully added to the current knowledge and practice of professional flight instruction, and serves to offer some additional and immediate areas for expanding the research conducted herein.

Appendices

Appendix A

IRB Approvals:

Metropolitan State University of Denver IRB Approval Letter

Nova Southeastern University IRB Approval Letter

METROPOLITAN STATE UNIVERSITY OF DENVER

Human Subjects Protection Program (HSPP)

Metropolitan State University of Denver
P.O. Box 173362, Campus Box 48, Denver, CO 80217-3362
303-352-7330 – hspp@msudenver.edu – www.msudenver.edu/irb/

APPROVAL

January 26, 2015

Dear Thomas De Cino:

On January 23, 2015 the IRB reviewed the following protocol:

Type of Review:	Revision
Title:	A Usability and Learnability Case Study of Glass Flight Deck Interfaces and Pilot Interactions through Scenario-based Training
Investigator:	Thomas De Cino
HSPP ID:	693332-2
Funding:	None
Grant Title:	None
Grant ID:	None
IND, IDE or HDE:	None
Documents Reviewed:	• Consent Form - De Cino CONSENT DOCUMENT(rev1.3) - MSU Denver (UPDATED: 01/15/2015) • Protocol - Flight Debrief Protocol (UPDATED: 01/15/2015) • Protocol - Observation Form - FN (UPDATED: 01/15/2015) • Protocol - Observation Form - TP (UPDATED: 01/15/2015) • Protocol - De Cino Research Protocol 1.3 - MSU Denver (UPDATED: 01/15/2015) • Questionnaire/Survey - Pilot Demographics Survey (UPDATED: 01/15/2015)

The IRB approved the protocol from January 23, 2015 to January 22, 2016. Before January 22, 2016, you are to submit a completed "FORM: Continuing Review (HRP-212)" and required attachments to request continuing approval or closure. It is recommended that you submit at least 30 days prior to expiration to allow adequate time for IRB review.

If continuing review approval is not granted before January 22, 2016 approval of this protocol expires on that date.

A stamped approved consent document is included in IRBNet with this decision letter. Use copies of this stamped document in accordance with your approved consent process.

In conducting this protocol you are required to follow the requirements listed in the INVESTIGATOR MANUAL (HRP-103).

Sincerely,

MSU Denver's Institutional Review Board

NOVA SOUTHEASTERN UNIVERSITY
Office of Grants and Contracts
Institutional Review Board

NSU

MEMORANDUM

To: Thomas DeCino

From: Ling Wang, Ph.D.
Institutional Review Board

Date: Feb. 4, 2015

Re: *A Usability and Learnability Case Study of Glass Flight Deck Interfaces and Pilot Interactions through Scenario-based Training*

IRB Approval Number: wang02151503

I have reviewed the above-referenced research protocol at the center level. Based on the information provided, I have determined that this study is exempt from further IRB review. You may proceed with your study as described to the IRB. As principal investigator, you must adhere to the following requirements:

1) CONSENT: If recruitment procedures include consent forms these must be obtained in such a manner that they are clearly understood by the subjects and the process affords subjects the opportunity to ask questions, obtain detailed answers from those directly involved in the research, and have sufficient time to consider their participation after they have been provided this information. The subjects must be given a copy of the signed consent document, and a copy must be placed in a secure file separate from de-identified participant information. Record of informed consent must be retained for a minimum of three years from the conclusion of the study.

2) ADVERSE REACTIONS: The principal investigator is required to notify the IRB chair and me (954-262-5369 and 954-262-2020 respectively) of any adverse reactions or unanticipated events that may develop as a result of this study. Reactions or events may include, but are not limited to, injury, depression as a result of participation in the study, life-threatening situation, death, or loss of confidentiality/anonymity of subject. Approval may be withdrawn if the problem is serious.

3) AMENDMENTS: Any changes in the study (e.g., procedures, number or types of subjects, consent forms, investigators, etc.) must be approved by the IRB prior to implementation. Please be advised that changes in a study may require further review depending on the nature of the change. Please contact me with any questions regarding amendments or changes to your study.

The NSU IRB is in compliance with the requirements for the protection of human subjects prescribed in Part 46 of Title 45 of the Code of Federal Regulations (45 CFR 46) revised June 18, 1991.

Cc: Protocol File

3301 College Avenue • Fort Lauderdale, FL 33314-7796 • (954) 262-5369
Fax: (954) 262-3977 • Email: *inga@nsu.nova.edu* • Web site: www.nova.edu/cwis/ogc

Appendix B

Consent Forms

Informed Consent Form

Permission to Take Part in a Human Research Study

Title of research study: A Study of Glass Flight Deck Interfaces and Pilot Interactions through Scenario-based Training

Investigator: Thomas J. De Cino

Why am I being invited to take part in a research study?

I invite you to take part in a research study because you are a General Aviation (GA) pilot training on glass flight deck interfaces at MSU Denver. You can participate in this study if you have: 1) a FAA issued private pilot license, 2) are working toward a FAA instrument or flight instructor rating/certificate, and 3) will be able to commit to 9-11 hours total over a 2-3 day scheduled period.

What should I know about a research study?

- Whether or not you take part is up to you.
- You can choose not to take part.
- You can agree to take part and later change your mind.
- Your decision will not be held against you.
- You can ask all the questions you want before you decide.

Why is this research being done?

This research study is investigating if flight instructor and pilot knowledge of GA aircraft glass flight deck systems is improved through implementation of scenario-based training approaches to the learning process of glass flight deck systems.

How many people will be studied? We expect about 6-12 people here will be in this research study.

What happens if I say yes, I want to be in this research?

You will receive instruction and training on glass flight deck systems and aircraft simulation technology by certified flight instructors. You will be asked to complete surveys and participate in group discussions regarding your training and learning experiences. The training and learning activities are being specifically conducted for this research study, and is not offered in the department's list of courses. There is no cost to you for participating other than the time spent to complete the training. All instruction, training, and use of aircraft simulators and other aviation technologies will be provided free of charge. There will be no compensation for your time and effort, if you agree to take part in this research study.

If you choose to participate, you will be taken through a typical aviation training process to learn about specific features of the glass flight deck system. The training will occur over an estimated 2-3 day period. Each training phase is be a mix of a traditional lecture/presentation of learning content, several scenario-based tasks and exercises, and hands-on training with the glass flight deck systems.

The lecture and training activities will be observed by the researcher. Observation and discussion notes, surveys, and questionnaires will be collected using a participant/pilot call sign and not the students' names. And, all research procedures will take place in designated classroom, laboratories, and training facilities in the AVS building.) During the training sessions and phases you will be asked to answer short questionnaire and survey forms.

Below is an outline of the pre- and post-training sessions and the training phases:

<u>Pre-training Orientation Session</u>

The pre-training orientation will include a review of the study's aim, and details about the two training phases will be presented. Discussion will take place describing and explaining the training phases. Below is a summary of what will occur:

- Overview of Training Phases and Types of Data Collection
- Completion of Pilot Profile & Attitudinal Questionnaire
- Approximately one hour and 30 minutes in length
- Occurs: First day of training regimen

In completing of the questionnaire, you will be asked to provide information about yourself (flight experience, year in school, degree/major, etc.) on a pilot (profile) demographics questionnaire.

<u>Training Phase #1</u>

You will begin training on glass flight deck systems with traditional classroom instructional materials. These will include the traditional textbook and general orientation lectures to GFD systems, the various components and their functional use, manufacturer and training operational systems manuals, and video demonstrations of the use of GFD systems in the real flight environment. After the traditional classroom instruction, an orientation to the CBT GFD system will be presented with hands-on exercises presented. You will have guided instruction on the use of GA glass flight deck simulated computer software to apply what they learned during the traditional lecture format. Below is a summary of what will occur:

- Lecture/PowerPoint/Textbook and OEM Manuals
- Computer-based Training (CBT) Format
- Guided Discussion and Self-paced Lessons
- Training Session: Approximately three hours in length.
- Occurs: First day of training regimen

<u>Training Phase #2</u>

The second phase of training will involve using scenario-based training (SBT), where you will fly an actual flight plan or scenario with the glass flight deck system. Your training activities will be completed in a flight simulation training device (FTDs) in the flight training laboratories. Below is a summary of what will occur:

- Scenario-based Training (SBT) Format
- Guided Flight Tasks in FAA-certified Flight Training Devices (FTDs)
- Entire Flight Plan in FAA-certified Flight Training Devices (FTDs)
- Training Session: Approximately four hours in length.
- Occurs: Second day of training regimen

Following each training phase, you will be asked to answer a survey form. The survey will ask you about your perceptions about how easy (or not) it was to use the equipment. Questions like "I found the GFD system easy…", or "I found the various systems difficult…" will be asked and for which you will respond using a strongly agree-strongly disagree rating scale. You will also participate in a verbal flight debrief or interview as a group with the investigator. You will be asked to respond verbally to questions about your flight and training experiences. Questions like "what did you like most about…", "what was the most difficult part of ….", and "why do you think that might have happened…" will be asked by the researcher.

Post-training Session

The post-training session is a flight debrief with the entire group. It will concentrate on a discussion of the scenario flight training format, and the use of scenarios to learn and master glass flight deck systems. We will discuss your perceptions of the impact of the scenario based training on your entire glass flight deck systems training experience. The final flight debrief will also provide you the opportunity to ask questions or get clarification on any aspect of the training, the data collected, or the study in general. You will also have the opportunity to offer additional feedback and input on your training experience. Below is a summary of what will occur:

- General Discussion, Flight Debrief, Study Review
- Approximately one hour in length
- Occurs: Second day of training regimen

What happens if I do not want to be in this research, or what happens if I say yes, but I change my mind later?

You are not required in any way to participate.

If you choose to participate, you can leave the research at any time, and it will not be held against you. There are no other alternatives to receive the same training in the department if you decline to participate. Not participating in or withdrawing from the study will not affect your academic standing, nor affect future course grades in any way.

Is there any way being in this study could be bad for me?

There are no risks or discomforts of any kind anticipated in this research study. This includes risks of physical, psychological, privacy, legal, social, or economic in nature. However, some individuals may experience stress while completing tasks on computer and flight simulator devices. For example, you may experience stress associated with executing an instrument approach or if a scenario requires you to execute a missed approach using unfamiliar equipment, but this should be no different than your normal training scenarios. Different people experience different levels of stress while completing tasks on computer and flight simulator devices, but the stress is normal, minimal, and not harmful to them.

Will being in this study help me any way?

Being in this study will give you exposure pilot information and training experience that reflects basic skills and knowledge acquired by pilots enrolled in a formal flight instruction program on glass flight deck systems.

We cannot promise any benefits to you or others from your taking part in this research. However, possible benefits include training and experience on glass flight deck components and systems. These benefits may inform your pursuit of additional pilot knowledge on glass flight deck systems, and may be directly applicable to future specific glass flight deck systems training you may choose to pursue.

What happens to the information collected for the research?

Efforts will be made to limit the use and disclosure of your personal information, including research study records, only to people who have a need to review this information. Although your personal information will be converted to anonymous identities, we cannot promise complete secrecy. Your information may be reviewed by MSU Denver's IRB that oversees human research or by other authorized representatives of MSU Denver. No other organizations for individuals will have access to any personal information you disclose, information regarding your training experience or other information you choose share.

When the study is completed, all study data will be maintained for a period of 3 years following its completion. This is in compliance with IRB guidelines and recommendations. Following the 3 year retention period prescribed, all identifiable personal information will be destroyed; only anonymous and researcher data (survey responses, group discussions, researcher observation notes, etc.) will be kept in anticipation of future research, and follow-up or replication studies. At this time there is no expectation that participants may be re-contacted in the future.

As noted, participant and group discussion records will be maintained in an anonymous (non-personal information) format. Participants are advised to observe non-disclosure rules by not disclosing responses and/or the identities of other participants during or after the study. All research data will be stored in the personal archives of the researcher, and after 10 years all study data will be destroyed.

Who can I talk to?

We will answer any questions you may have about this study. If you have questions, concerns, or complaints, or think the research has harmed you, talk to the researcher at decinot@msudenver.edu, or via office telephone at 303-556-6174, or cell telephone at 303-594-8619.

This research has been reviewed and approved by an Institutional Review Board ("IRB"). If you would like to talk with someone other than the researcher(s), have questions about your rights as a study participant, or have questions or complaints that are not being answered by the researchers, please contact MSU Denver's Human Subjects Protection Program at 303-352-7330 or by email at hspp@msudenver.edu.

Signature Block for Capable Adult

Your signature documents your permission to take part in this research.

______________________________ ______________
Signature of subject Date

____
Printed name of subject

______________________________ ______________
Signature of person obtaining consent Date

____
Printed name of person obtaining consent

January 23, 2015
MSU Denver's IRB Approval Date

Permission Statement for Anonymous Surveys

Title of research study:

A Usability and Learnability Case Study of Glass Flight Deck Interfaces and Pilot Interactions through Scenario-based Training

Investigator:

Thomas J. De Cino

Study Purpose:

The purpose of this study is to investigate if flight instructor and pilot knowledge of GA aircraft glass flight deck systems is improved through implementation of scenario-based training methods to the process of learning glass flight deck systems. You have been invited to participate because you are a General Aviation (GA) pilot training on glass flight deck interfaces in pursuit of an instrument or certified flight instructor rating. You must be 18 years of age or older to participate.

Your Participation:

Your participation will involve traditional classroom work, work on computer-based training programs, and work in and with aircraft simulation systems. Online/Internet surveys will be used to collect information on your perspectives on the training process and the learning experience. The survey includes questions such as phrases as "on a scale of strongly agree to strongly disagree, answer the following questions", or "rank the following training phases from most effective to least effective". Most questions will allow for a single or simple answer; a few questions may ask you for more detailed answers. Your involvement in the research surveys should take approximately 20-30 minutes each to complete. You may answer only the questions you feel comfortable answering, and you may stop participating at any time for any reason.

Identifying Information & Anonymity:

Please do not put your name on the survey. No identifying information will be collected. If published, the results of this study cannot be linked to you as a participant. There are no known risks in this study. There is no direct benefit to you for participation; however the results of this study will provide information on the benefits, if any, of using scenario-based training methods in pilot training on glass flight deck systems. All of the information collected will be stored securely in the Principal Investigator's office, where only the researcher has access to the data. For you the participant, there are no costs or compensation associated with this study.

Your participation is completely voluntary and you may choose not to participate. By completing the surveys online, you are agreeing to participate in the research study as described above. Please keep this consent statement for your reference.

Questions and Concerns:

Any questions or concerns should be directed to the Principal Investigator, Thomas De Cino, by phone at 303-556-6174, or by email at decinot@msudenver.edu. This research has been reviewed and approved by an Institutional Review Board ("IRB"). If you would like to talk with someone other than the researcher(s) or have questions about your rights as a study participant please contact MSU Denver's Human Subjects Protection Program at 303-352-7330 or by email at hspp@msudenver.edu.

Thank you for your consideration.

Sincerely,

Thomas J. De Cino

WIA Laboratories Manager
Aviation & Aerospace Science Department - MSU Denver
Ph.D. Graduate Student
Nova Southeastern University

Appendix C

Site Access and Approval

Site Access and Approval Letter

October 1, 2014

Dr. Jeffrey S. Forrest, Chair
Aviation and Aerospace Science Department
Metropolitan State University of Denver
1250 7th Street
Denver CO. 80204

Dr. Forrest:

Please accept this as my formal request for your permission and support for access and use of the Aviation and Aerospace Science Department's facilities. I am currently pursuing the completion of my Ph.D at Nova Southeastern University of Fort Lauderdale, Florida, and I am nearing final preparations for executing my research study.

I would like your approval to utilize laboratory classroom space, CBT systems, and aircraft simulation equipment in the AVS Department building. As part of the process of completing my dissertation, my research study focuses on the training experience student pilots and flight instructors have when learning to use and master aircraft glass flight deck systems.

I appreciate your consideration in accessing and using these resources as they are instrumental in completing my study. If you need a copy of my dissertation proposal for more details on the study, please let me know. If you approve and grant permission for use of these resources, please sign and date in the appropriate area below and return to me at your convenience.

Thank you in advance!

Thomas J. De Cino

By my signature below, I give my permission and support to Thomas J. De Cino to have access to, and use the AVS Department resources as requested above. Mr. De Cino has the approval to utilize these resources to whatever extent needed to meet the needs of his dissertation research study.

Dr. Jeffrey S. Forrest, Chair – AVS Department

10-2-14
Date

Appendix D
Protocol Forms

Recruitment of Participants - Email and Print Protocol

The following information will be sent in the body of an email to students enrolled in a Midwestern aviation university focused on training professional pilots. It will also be printed as a single page flyer and hung in the campus building of the Midwestern aviation university. The primary objective of both means of communication is to advertise the opportunity and invite participation for student pilots as participants of this research study.

Glass Flight Deck Systems Research Study in AVS Department Announced!

Are you starting instrument or flight instructor training? Do you want to learn more about today's glass flight deck systems? Are you willing to participate in a 4 day-long research study? If so, consider participating in this research study!

This research study will look at improving training of GA aircraft glass flight deck systems. We expect about10-12 people will be needed for this research study.

Here is what you can expect:

- You will receive specialized instruction and training on glass flight deck systems and aircraft simulation technology by certified flight instructors.
- You will be asked to complete surveys and participate in group discussions regarding your training and learning experiences.
- All instruction, training, and use of aircraft simulators and other aviation technologies will be provided free of charge.
- There is no compensation for your time and effort.

Training is intended to improve pilot knowledge on glass flight deck systems.

While we cannot promise any specific benefit to you, possible benefits include specialized training and experience on specific glass flight deck components, systems, and special access to glass flight deck training software and flight training devices to enhance your pilot skills flying glass flight deck systems.

To get more information and details, or to apply to participate please send an email to wialabs@gmail.com or ask for TJ De Cino, WIA Lab Manager in the AVS Department's World Indoor Airport.

Flight Debrief Protocol

<table>
<tr><td>Phase:

Date:

Day:

Time:</td><td>Participant Call Signs:</td></tr>
<tr><td>Setting/Environment:</td><td>Key notes:
words, tone of voice, posture, eye contact, non-verbal actions, physical behavior, overall behavior

New questions that arise?

Observer’s Comments on:</td></tr>
<tr><td colspan="2">Key notes:
Welcome statement and thanks for participating
Introductions
Describe purpose of FG interview and the remind of the larger purpose of the study
Estimated length of FG interview time; researcher notes taken for later analysis and transcription
No names attributed to comments; full participation encouraged and needed
Ground rules for participation (identify & define; e.g. one speaker at a time; equal participation)
Explain role as facilitator
Closing remarks
End with thanks for participating and give contact info if want to share anything forgotten to say.</td></tr>
</table>

Question #1 – General Experience with the Training Phase

Let’s begin with a discussion of the today’s training session and the overall experience you have had. Start by focusing on how your individual learning process went, and your perceptions on the training materials and equipment.

Answers/Comments:

Additional inquiry/follow-up?

Question #2 – General Experience with Use of Scenarios to Learn Materials and Equipment

I would like to now focus on your experience and perceptions of using training scenarios with the training materials and computer and simulation equipment used. Let's discuss your experience with how the training scenarios affected your ability in learning to use and master the training materials and equipment.

Answers/Comments:

Additional inquiry / follow-up?

Question #3 - Specific Experiences with Use of Scenarios to Learn Materials and Equipment Complete the Training Phase

Now let's focus on your experience and perceptions with specifically using the training scenarios. Let's discuss what your experiences were regarding your ability to use the training equipment – problems or successes with operating the equipment, difficulties or ease of using the equipment while completing the training scenarios.

Answers/Comments:

Additional inquiry?

Question #4:

Based on your training experience, let's talk about the extent to which you feel you have mastered the training scenarios. Do you feel like you are now competent in being able to repeat or duplicate the training scenarios successfully?

Describe whether or not these training scenarios make you feel like you can effectively apply these skills in the real aircraft while in flight? How – in what ways?

What aspects about the scenarios taught are lacking or need additional attention in the training process in order to be able to be totally confident applying these skills in flight in a real aircraft?

Answers/Comments:

Additional inquiry?

Question #5:

Let’s take this time to address any final questions or comments you may have. This is also a good time to clarify any answers you may have provided to any of the previous questions. Feel free to discuss anything or provide any feedback you have. I may ask a few follow-up questions as well.

Questions / Answers / Comments:

Additional inquiry?

Observation Form – Field Notes

Page No.

Phase: Date: Day: Time:	Key notes: words, tone of voice, posture, eye contact, non-verbal actions, physical behavior, overall behavior, particular participant call sign, etc. New questions that arise? Observer's Comments on:
Setting/Environment:	
Activity/Event/Observations:	

Observation Form – Training Phases

Phase: Date: Day: Time: Participant Call Sign(s):	Key notes: words, tone of voice, posture, eye contact, non-verbal actions, physical behavior, overall behavior New questions that arise? Observer's Comments on:
Setting/Environment:	
Activity/Event/Observations:	

Final Training Debrief Protocol

Pilot Call Sign:

Just want to point out a few key things on this Final Training Debrief!

First and foremost thanks for participating! Without your completing this final form my study, while likely good, will not be great! No pressure here! ;-)

This final interview on paper is your opportunity to give me a narrative or story of your overall training experience.

Like journals you have probably done for other experiences, you are totally at your discretion to write as you feel. It doesn't matter if you write in bullet points or phrases, or in full sentences like writing a novel.

Be as long winded as you like – the more the better!!!

What matters most here is your best effort to describe your overall training experience:

- Tell me about your training with specific regard to using Scenario-Based Training (SBT)
- How Usable the G1000 GFD system was
- Absolutely feel free to compare (or not!) the CBT training versus the FDT training phases
- Talk about the time commitment you made to complete the training
- Describe the Stress or Elation you experienced
- Add whatever you like – make it totally your story

Use these areas above to get the writing juices flowing. Use as a starting point or answer them directly – totally your call.

The point is to get your entire reflection down on paper as to the overall training experience you had! BOTH GOOD and BAD!

As always, feel free to contact me via phone or email with questions.

A Final Note:

I would appreciate you <u>not taking more than 3 days to complete and return this to me</u> as I want the experience to be fresh in your mind as you write and share.

Question #1 – Tell me about your training with specific regard to using Scenario-Based Training (SBT).

Question #2 – How Usable was the G1000 GFD system? On the CBT system? On the FTD system?

Question #3 – Compare (or not!) the CBT training versus the FDT training phases.

Question #4 –What about the time commitment you made to complete the training?

Question #5 –Describe the Stress or Elation you experienced, or any other perceptions or feelings you have.

Question #6 – Is there anything else you would like to add - whatever it may be?
(Future training, goals, expectations, participating in research studies, etc.)

Appendix E

Instrumentation

Pilot Demographics Questionnaire

1. Please enter your participant call sign (your choice - 5 characters and/or numbers):

____

2. What is your current academic year status?

Freshman Sophomore Junior Senior
Other (please specify)________________

3. What is your major? (Circle primary degree)

Professional Pilot Officer Air Traffic Control Aerospace Management IDP

Other (please specify)___________________

4. What is your current status as a pilot? (Circle all attained that apply)

Private Pilot Instrument Rating Commercial Pilot Multi-engine Rating CFI/II
Other (please specify) _________________

5. Please list many total flight hours (for each certificate or rating you have. (Number of flight hours listed should be what is in your official FAA flight log records.)

Private Pilot _________________

Instrument Rating _________________

Commercial Pilot _________________

Multi-engine Rating _________________

CFI/II _________________

Other (please specify) _________________

6. Of your total flight hours (all types), how many flight hours have you logged as instrument flight? (Circle range that best describes what is in your official FAA flight log records.)

0-10 hours 11-25 hours 26-50 hours 51-100 hours 100+

7. How many inflight VFR hours have you logged using glass flight deck systems or technically advanced aircraft (TAA) components? (Circle range that best describes what would be recognized officially according to FAA flight standards.)

0-5 hrs 6 - 10 hrs 11 - 25 hours 26 -50 hours 50 - 75 hours

75+ hours

8. How many inflight IFR hours have you logged using glass flight deck systems or technically advanced aircraft components? (Circle range that best describes what would be recognized officially according to FAA flight standards.)

0-5 hrs 6 - 10 hrs 11 - 25 hours 26 -50 hours 50 - 75 hours

75+ hours

Glass Flight Deck (GFD) Attitudinal Survey (Pre- and Post- Training)

Please review each statement carefully and circle the number corresponding with the extent of your agreement or disagreement with the statement, using the Disagree/Agree rating scale to the right.	Strongly Disagree | | 1	Disagree | 2	Neutral 3	Agree | 4	Strongly Agree | | 5
1. They've gone too far with advanced cockpit systems.	1	2	3	4	5
2. I look forward to new kinds of advanced cockpit systems.	1	2	3	4	5
3. The advanced cockpit does not make good use of my basic piloting skills.	1	2	3	4	5
4. In an advanced cockpit, sometimes I feel more like a 'button pusher' than a pilot.	1	2	3	4	5
5. Advanced cockpit systems can get you into trouble just as easily as they can get you out of trouble.	1	2	3	4	5

6. If you care to share any particular comments about your general attitude to this study, the training program, or in learning/using glass flight deck systems, please provide your comments below:

Glass Flight Deck (GFD) Usability Survey

System Usability Scale (modified)

Date: ____________________ Pilot Call Sign: _____________________
Training Phase #: _________ Notes:

Please answer each question carefully using the Disagree/Agree rating scale to the right.	Strongly Disagree | | 1	Disagree | 2	Neutral 3	Agree | 4	Strongly Agree | | 5
1. I think that I would like to use the GFD system frequently.	1	2	3	4	5
2. I found the GFD system unnecessarily complex.	1	2	3	4	5
3. I thought the GFD system was easy to use.	1	2	3	4	5
4. I think that I would need the support of a technical pilot to be able to use the GFD system.	1	2	3	4	5
5. I found the various functions in the GFD system were well integrated.	1	2	3	4	5
6. I thought there was too much inconsistency in the GFD system.	1	2	3	4	5
7. I would imagine that most pilots would learn to use the GFD system very quickly.	1	2	3	4	5
8. I found the GFD system very cumbersome to use.	1	2	3	4	5
9. I felt very confident using the GFD system.	1	2	3	4	5

10. I needed to learn a lot of things before I could get going with the GFD system.	1	2	3	4	5

11. Regarding this training phase and your learning experience, do you have any additional comments or statements you would like to share?

Appendix F

Supplemental Data:

SBT Flights – Duration Analysis

SBT Flights – Duration Analysis

The CFI made hand written notes in the form of time stamps and simple phrased-based notations for all of the flight segments executed by each of the participants while conducting the scenario-based flight. The primary notes recorded allowed the CFI to capture time and duration information to enable the CFI to keep the participants "on-task" during the estimated sixty-five minute scenario-based flight plan. The researcher created the flight scenario protocol feeling it was important a.) to limit the potential level of participant stress from problems or frustrations arising or experienced during the flight scenario, b.) to insure each participant experienced essentially the same flight scenario requirements and conditions, and c.) to avoid having excessively long or drawn out flights that would have negatively affected other participant start times for succeeding flights as scheduled. The time-to-complete statistics for each of the participant's flights are presented in a following section.

The additional dataset that emerged was "time-to-complete" data for each participant on the specific SBT flight subtasks (unique segments or "legs" to the flight), and was quite informing. The data emerged from the final tally results of the CFI's efforts in following the detailed flight scenario plan each participant was required to execute. These individual participant "time-to-complete" tasks are time-stamps on the CFI's flight tracking script used for each of the participant flights. The use of the CFI flight tracking script originally was intended to a.) systematize the CFI's role as an air traffic controller, b.) keep each participant on a reasonable but demanding flight schedule as might be experienced in the real world, and c.) insure each participant followed the same flight scenario plan, and d.) keep all scheduled flight scenarios on time (start and end).

Following the scripted flight scenario, the CFI recorded notations that captured flight segments time stamps as part of the timing and duration planning for the entire flight. This allowed the researcher to insure the scenario-based flights stayed relatively on schedule as would occur in the real world. Keeping the participants "on-task", the CFI's hand written notes on the flight script (time stamps and simple phrased-based notations) revealed enough time and duration information to be useful in developing simple statistics for all of the flight segments executed by each of the participants while conducting the scenario-based flight.

Upon review of the timing and duration data, five different time stamps were captured for the various segments or "legs" of the flight scenario. The time stamps reflected the time the participant began the FTD flight scenario, the time the participant requested departure clearance, the time the participant requested take-off clearance, the time at which the participant requested air traffic control assistance (emergency declaration), and the time at which the participant landed the aircraft. Calculations for duration of time between these time stamps for key flight segments rendered simple statistical information for each of the participants.

The five flight scenario segments are listed :

1. Time spent to prepare, utilize checklists, and entering the flight plan necessary to setup the FTD for the flight scenario,

2. Time spent on final aircraft preparation and checks – time between receiving departure clearance and requesting take-off clearance
3. Time in flight between take-off and declaring emergency and requesting ATC assistance
4. Time spent in the air in flight from take-off to landing
5. Total time spent on completing the scenario-based flight – from beginning the FTD setup process to the landing back at the airport

In general, most of the participants were similar in their time spent to complete the various flight segments. One note however is appropriate here. One of the participants (Participant #5) did experience more difficulty than the rest when completing the entire flight scenario and this shows up in the participant's time spent on each of the flight segments. The researcher calculated two different sets of simple statistics as a result. Given Participant #5 did experience approximately 25-30% more time to complete the entire flight scenario compared to the other participants, calculations including of the Participant #5's flight segment duration data, as well as calculations excluding the Participant #5's data were made. For example, the time spent to setup the FTD for the scenario flight (prepare the FTD, run checklists, and enter flight plan) ranged between 16 minutes and 31 minutes with the participant's data, while the range was only 16 minutes to 25 minutes without the Participant #5 data. Table F10 presents the participants' flight segments duration calculations.

Table F10

Participant Time Spent: FTD Scenario-based Flight Segments

	Time (hrs:mins:secs) -- >				
	Time for FTD Setup	Final Aircraft Check	Emergency Declaration	Time in Flight in Air	Total SBT Flight Time
Participant #1	31:00	17:00	41:00	1:06:00	1:39:00
Participant #2	20:00	7:00	19:00	46:00	1:06:00
Participant #3	16:00	3:00	19:00	51:00	1:11:00
Participant #4	19:00	4:00	20:00	47:00	1:09:00
Participant #5	31:00	17:00	41:00	1:06:00	1:39:00
Participant #6	25:00	18:00	17:00	46:00	1:11:00
Participant #7	20:00	6:00	17:00	46:00	1:06:00
Mean Time (including #5's data)	22:20	8:36	21:42	49:36	1:13:24
Mean Time (excluding #5's data)	20:48	*not calculated	18:30	46:48	1:09:12

Note: Mean times calculated from averaging of all participant times, with and without outlier figures from Participant #5. **Exception*: Final Aircraft Check time without Participant #5 not calculated as another participant in the group also took a similarly long time and thus was an additional outlier figure for this specific segment of the flight scenario.

From the above table one can see the means times for nearly all flight segments for all participants are similar or close in duration times. When excluding Participant #5 data, flight segment duration times are much closer to the mean, and all fall within approximately 10-15% or less of the mean times shown. The researcher scripted the original flight scenario to be executed in approximately sixty to sixty-nine minutes based on real-world flight times. The researcher concludes the participant group time figures (minus Participant #5 data) are appropriate and reasonable for the SBT flight as planned, and reflects what a real world small GA commercial flight using the GFD system would present in such a situation. Furthermore, as no unplanned anomalies or GFD system level problems arose, the researcher can confidently conclude all the participants experienced essentially the same flight scenario and thus their perspectives and opinions discussed in the next sections accurately reflect their experience with the GFD training system used in and actual scenario-based flight plan.

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