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Disrupting aviation: an exploratory study of the opportunities and risks of tablet computers in commercial flight operations

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DISRUPTING AVIATION: AN EXPLORATORY STUDY OF THE OPPORTUNITIES AND RISKS OF TABLET COMPUTERS IN COMMERCIAL FLIGHT OPERATIONS

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ABSTRACT

Commercial flight operational safety has dramatically improved in the last 30 years because of enhanced crew coordination, communication, leadership and team development. Technology insertion into cockpit operations, however, has been shown to create crew distractions, resulting in flight safety risks, limited use given policy limitations and difficulty in establishing standard operating procedures. With the recent introduction of tablet computers into the flight cockpit as a substitute for paper-based manuals and navigation charts, the risk of human error may be increased. Though portable electronics, known as electronic flight bags, have been present of the flight deck for a decade, introduction of tablet computers as their replacements offers unique challenges, given the ability to communicate and share information outside established aviation channels. This research explored the opportunities that this technology insertion offers to commercial aviation in areas such as knowledge sharing and operational performance improvement. The results indicate that the opportunities were not realized with the initial implementation because the pilots did not accept the technology due to inadequate training coupled with restrictive policies concerning use.

Chapter 1: Introduction

Throughout history advances in technology have created disruptive forces within larger sociotechnical systems (Christensen, 1997; Schumpeter, 1934). The forces arise from applications or results produced from use of innovative technology that yield unexpected outcomes. In Schumpeter's (1934) classic example, railroads, as a transportation technology, came to creatively destroy agriculture in areas around Midwestern U.S. cities because the railroads could bring in produce at a lower price than the local farmers could grow the same food. As railroads needed land for marshaling yards the farmers found it more profitable to sell their farmland to the railroads. In 1870 it is unlikely any farmer saw a threat to his or her livelihood arising from a railroad (Schumpeter, 1934).

Schumpeter (1975) described this process as creative destruction since a segment of a society was destroyed by an unexpected, creative competition enabled by technology. Building upon Schumpeter's work, Christensen and Raynor (2003) used the example of personal computers originally designed for children's use in schools, as creating unexpected competition with mainframe computers. As the personal computer's capability increased, the high cost of the mainframes no longer could be supported and the industry was disrupted from an unexpected market entry. Other examples used in Christensen, Horn, and Johnson's (2011) study have to do with the impact cell phones as musical access devices have had on the music industry and consumer electronics. Again, a technology made for communication created the disruption of an industry from an unseen direction because of a low cost technological entry into a higher priced market in which the low cost technology performed well.

Beginning in May of 2011 iPads from Apple Computer were authorized for use in airline cockpits during flight. iPads have not been used in commercial flight; the technology was not designed for use in flight, nor has there been study as to the impact upon the complex sociotechnical culture inside the cockpit (M. Yeh, personal communication, September 28, 2011). Airline flight is a carefully planned and executed event that is dependent upon pilots focused primarily upon safety and is based upon a culture of safety. The technology resident in the iPad creates opportunity for a low cost entrant to disrupt an industry as described by Christensen (1997) and creatively destroy market conditions as described by Schumpeter (1934).

Christensen (1997) describes a "job" as being the use of the technology from the user's point of view. Managers rarely understand the "job" from the same perspective. The research may uncover the importance of the role of the "job" to the creative destructive potential of iPads in commercial flight operations suggesting a predictive factor for creative destruction.

Airline travel has become significantly safer since 1983 and one of the contributing factors is the enhanced culture of safety awareness brought on by specific team development training for the cockpit, known as crew resource management (CRM; Baker, Qiang, Rebook, & Li, 2008). CRM focuses upon crew coordination facilitated with enhanced communication while developing a greater team sense of threats and risks in flight.

CRM creates enhanced situational awareness (SA) by the cockpit team enabling earlier recognition of threats coupled with error avoidance and rapid containment of threats (Endsley, 1995). SA is concerned with the cockpit crew's perception of the environment critical to decision making in response to those risk and threats (Endsley, 1995). SA is related and integral to CRM in a systemic way being an input to; process and output from intelligent CRM while simultaneously relying upon CRM to enhance the level of SA. If CRM captures the necessary team dynamics, SA is symbiotically improving CRM while simultaneously being improved by CRM (Dostal, 2007; Endsley, 1995).

A sound cockpit culture focuses upon safe flight enabled by expertly executed crew coordination and a high sense of mutual awareness. The iPad's ability to connect users to immediate information is an opportunity to generate enhanced SA. The outcome of any technology integration into commercial airline flight operations is the enhancement of SA, which improves flight safety for passengers as well as productivity for the airline (Endsley, 2010; Weiner, 1988).

This exploratory study sought to understand the opportunities and risks that the introduction of tablet computers might create within the airline flight environment and the possible impacts of the tablets upon safety awareness developed from CRM and SA. The Federal Aviation's research branch charged with evaluating portable computer use in the cockpit has indicated that there has been no research on the iPad in the flight environment as to pilot acceptance of the technology, CRM, SA, required training, integration into flight procedures or information sharing between aircraft and other flight agencies (M. Yeh & D. C. Chandra, personal communication, September 14, 2012). This exploratory study will attempt to begin to understand the opportunities and risk with portable computing in flight operations.

Fictional Case Example

The fictional case example is onboard Flight 678 from Kona to Los Angeles 0400 Saturday, September 21, 2012. The flight had departed Kona on time for the 5-hour flight back to the Mainland. At 35,000 feet the sky was clear with a bright moon overhead as the aircraft proceeded northeast and about 650 miles southeast from Los Angeles. Though the autopilot was engaged, the Captain as flying pilot was monitoring the instruments and noting that the nearest point to land given the curvature of the U.S. west coast was San Francisco. The aircraft was a 2-year-old Boeing 737-900ER configured with Internet access. Given the failure of the commercial aircraft industry to update transoceanic communications since the 1960s, the aircraft was only able to communicate by voice via a very scratchy high frequency radio system. However with Internet capability through satellite feeds the First Officer was checking weather in Los Angeles as well as airport systems availability via his iPad. A predicted storm front had passed through the Bay Area and was now causing heavy rains and severe winds in the Southern California area.

The Captain asked the First Officer for the fifth time if he had caught the USC-Oregon game the day prior while they were on their layover at Kona. USC had been on the receiving end of a 51-20 beating from Oregon. The First Officer, a USC graduate and former Navy F/A-18 pilot then asked the Captain, a former Air Force A-10 pilot and Oregon graduate, if he had ever flown a real airplane before he was hired at the airline. The conversation was interrupted as a right engine fire light illuminated, coupled with a violent shaking of the airframe and banging sounds from the right engine side. A mechanical failure of the engine's compressor turbine resulted in a seizure of the engine, ruptured fuel lines causing fire to spread throughout the engine. The Captain immediately decoupled the autopilot as the First Officer executed the immediate action procedures to fight the fire.

Once the fire was extinguished the Captain eased the flight off the standard trans-Pacific track and began a gradual decent since the thrust from the single remaining engine was not adequate to maintain level flight at a high altitude. The First Officer consulted with his iPad and noted that level flight for their aircraft's fuel and weight would be at 22,000 feet. Given preflight planning entered into the iPad along with updated winds automatically gathered from the Internet, fuel was automatically recalculated to verify a safe arrival with 45 minutes of fuel remaining at Los Angeles.

The high frequency radio was used to relay an emergency call to the transoceanic flights while simultaneously alerting other flights in the vicinity. The First Officer established email contact with the company's operation center and asked for a Skype conference to include maintenance, operations and management personnel. The high frequency system did not have the range or bandwidth to host such an effort.

While the Captain was coordinating with flight attendants, assuring passengers that the situation was stabilized and flying the aircraft, the First Officer was programming in criteria for success and alternative solutions into his iPad transmitting the problem to headquarters via the Internet. Embedded in the iPad was a complex decision assistance system that allowed application of the Analytic Hierarchy Process to execute pair wise comparisons and calculate the optimum decision path for consideration by the team. Any member could automatically vote into the system from the Web, building team awareness as to the best decision.

Given the weather and equal distance position between Los Angeles and San Francisco, the iPad reported that flight to San Francisco was the alternative selected by the votes using the algebraic programs in the iPad's application. As the First Officer relayed the results to the Captain, discussion arose about the status of runways at San Francisco and Oakland as a backup. These elements were relayed via email to headquarters and information as to status received back 3 minutes later. The crew decided with the concurrence of headquarters to proceed to San Francisco.

Current State

The previous scenario is not a possibility unless and until an aircraft is equipped with satellite communication and this capability now resides only in the larger aircraft as the Boeing 767, 777 and the 747 and their Airbus equivalents. The majority of today's flights depend on the antiquated high frequency radio capability for flights to and from Hawaii. Though flights within the United States have clearer radio communications, the same problem of access to real time weather and system information remains constant. As airlines introduce iPads into the cockpit for flight operations a host of opportunities and risks remain to be explored (M. Yeh, personal communication, September 28, 2011). Currently, the options and decisions depicted in the fictional, opening scenario would be generated and made by the Captain and First Officer alone, in the cockpit, given 3-hour old information from the preflight briefing.

Background

Airline travel continues to remain the safest form of rapid transportation for the American public. A large reason for the continued safe performance of the air travel system is that the number of mishaps related to pilot error, as defined in commercial aviation by poor decision making as a result of poor crew communication and coordination, has been reduced by 71% from 1983 to 2002 (Baker et al., 2008). The overall mishap rate remained fairly stable over the study cited, but the proportion of mishaps involving all pilot error decreased from 42% in 1983–87 to 25% in 1998–2002, yielding a 40% reduction in aircraft accidents attributed to pilot mistakes (Baker et al., 2008). Those mishaps related to poor decisions caused by improper crew coordination, communication, leadership or resource management declined from 6.2 to 1.8 per 10 million flights, yielding the 71% reduction. The largest contributor to the 71% reduction had to do with pilot decisions regarding landing or takeoff in hazardous weather conditions. Statistically, misjudging wind or runway conditions declined by 78% as the major contributor to the overall 71% decrease (Baker et al., 2008). The rate of mishaps specifically involving poor crew interaction or poor communication has declined by 68%. Mishaps during takeoff had declined by 70%, from 5.3 to 1.6 per 10 million flights. As a counter to better cockpit safety, the large trend in overall reduction was offset by an increase in mishaps while the aircraft was not moving, from 2.5 to 6.0 per 10 million flights, and during push back from parking at the airport gates, which increased from zero to 3.1 per 10 million flights (Baker et al., 2008). These areas of increase occur generally outside of a pilot's control while the aircraft is being towed or parked.

Baker et al. (2008) indicate that safety trends may possibly be improving due to enhanced pilot training in crew coordination, as well as the contribution of technology increasing pilot awareness of environmental and aircraft system performance. Since 1981, airlines in the United States have implemented specific training designed to improve management of cockpit technology and team dynamics within the aircraft, as well as with air traffic controllers, flight attendants and flight operation managers (Salas, Shuffler, & DiazGrandos, 2010). The training and education system was originally known as cockpit resource management, but since the late 1980s has been called crew resource management (CRM), emphasizing the integration of information from all members of a flight safety system. Salas et al. (2010) recently described CRM as a set of instructional strategies designed to improve the behavior, cognition and attitudes that compose team work and management of technology in airline flight in order to achieve mutual goals meeting the operational demands of the outside environment while ensuring safe flight execution.

Endsley (2010) maintains that the outcome of improved CRM is superior SA. SA is the understanding of current and future threats and opportunities within the operating environment. Superior SA results in safer flight and higher operational efficiencies.

The introduction of a new piece of equipment, such as a tablet computer, inside the cockpit of an airliner places additional demands on an already full training program and in-flight workload with regards to CRM and SA (Yeh & Chandra, 2010). Given indications that CRM building enhanced SA and technology have played a significant role in saving lives that may otherwise have been lost to aircraft accidents, implementation of the technology suggests research in the proper integration of the tablets, from a systems perspective, be considered essential, if not paramount. High-risk operations within complex sociotechnical systems require that a minimum acceptable level of proficiency be defined, and which all crewmembers must meet. An additional goal is also to achieve this proficiency as cost effectively as possible for airline companies given the profit and loss motivation (Chandra, Yeh, & Riley, 2004). By identifying the set of knowledge and skill requirements that meet mission requirements, and using instructional techniques most appropriate for adult operators, the airline can produce training that is both efficient and effective for aircrew to best integrate new technology into the dynamic flight regime.

Training for airline crews may involve distributed or onsite study. Different types of training may be needed for completely new users to both cockpit technology as well as new hires to the airline, users who are transitioning to new aircraft, and those who are undergoing annual proficiency reviews. The proficiency and experiences of the user as to tablet computers must be taken into account. The training programs will also likely vary based on the variety and criticality of applications on the tablet computer dependent upon stage of planning or operation. Training for initial users may need to be integrated throughout their training on all aircraft systems, whereas training for more experienced users could be separate from training on other aircraft systems. As with any information system, training programs may have to be updated along with the tablet's software or hardware updates, unless the change is judged to have minimal impact upon operations so that an internal information bulletin or equivalent would be an acceptable substitute.

Portable Computing in Airline Flight Operations

> The rapid pace of introduction of computer-based devices into the cockpit has outstripped the ability of designers, pilots, and operators to formulate an overall strategy for their use and implementation. Putting "just one more computer" into the cockpit is not the answer. The solution will come from a long, expensive and sometimes tedious effort to develop a harmonious crew-automation interface, guided by an overall design philosophy. (Weiner, 1988, p. 433)

Portable computers have been used in flight operations since FEDEX introduced laptop computers loaded with flight specific software to calculate technical details such as takeoff parameters, weight and balance constraints and landing distances in 1991. The computers replaced lengthy manual calculations and less accurate graphical solutions (Chandra et al., 2004). As computing power became greater and weight of the devices decreased, commercial carriers such as Southwest Airlines and JetBlue integrated the laptops into aircraft operations again primarily for performance calculations. In 1997, study began as to the possibility of moving navigational charts, emergency procedures, airport diagrams and flight manuals to laptops replacing the physical flight bag pilots carried with such data, with an electronic version called the electronic flight bag (EFB).

Though originally approved for use by the Federal Aviation Administration (FAA) in 1999, the major United State carriers (United, American, Delta and US Air) have not implemented the EFB plan due to cost of the technology and concerns about cockpit integration from the crew perspective (Chandra & Kendra, 2009). Pilots have carried the physical version an EFB in large attaché cases since World War Two. The attaché package is composed of paper charts, manuals and data weighing up to 48 pounds and requires constant updating. As the price of aviation jet fuel rose in 2008, and with the advent of powerful, low-cost, tablet computers in 2009, the savings in fuel in reduced weight created a point at which tablet computers became a viable alternative for the paper versions and beat the price of laptop based EFBs. The savings in fuel due to the removal of heavy paper manuals, along with the enhanced computing power at a lower price, has created a business case to implement tablet computers that stored the navigation and technical data. Eliminating the weight of the physical bag is estimated to reduce fuel usage for U.S. air carriers by over 1.4 million gallons of jet fuel, greenhouse gas emissions by 12,900 metric tons and save 64 million sheets of paper every year (Warren, 2011).

The FAA classifies three separate types of EFBs (FAA, 2011). The first, called Type A, is a stand-alone portable computing device that is not physically or electronically connected to the aircraft and must be stowed safely during takeoff and landing events. The second category, called Type B, is physically attached to the aircraft via brackets or a rack but not integrated into the avionic or electronic system. The third category, called Type C, is part of the aircraft's suite of electronics and functions as an integral part of the aircraft's computing power. Each of these classes may execute a type of function. Type A EFBs function as static displays for checklists or airport diagrams. Type B EFBs have the ability to scroll, expand or minimize such as navigation charts and Type C allow multiple functions such as engine displays or flight instrument data. Tablet computers fit within the first class, as a stand-alone device not connected to the aircraft in anyway and either a Type A or B display. Instructions from the FAA in March 2011 identified commercial, off the shelf tablet computers such as the iPad as fitting within the realm of EFBs. This directive means the U.S. government has authorized tablet computers for use in airline cockpits (FAA, 2011).

Introduction of iPads to the Commercial Cockpit

Kirby (2011) described intended introduction of the iPad tablet computer by Alaskan Airlines into the flight environment. The iPads have been specifically modified by Jeppesen, a unit of Boeing Flight Services, with applications to carry and display navigation, airport and radio frequencies. Jeppesen's solution is the only FAA-authorized in-flight paper replacement system and provides operators with real-time route planning capabilities and GPS-based positional awareness in flight. Enhanced full-color, high-quality, vector-based data with chart search and zoom features allow greater detail to be rendered on the iPad's display. The capabilities to enter operational notes and share information between crewmembers are additional features of the new digital enroute charting application (Kirby, 2011). Pilots are also able to choose what flight data are displayed, including airports, airways, waypoints, navigational aids, and airspace, as well as terrain information. This feature allows for an on-screen presentation that can be customized to each pilot or crew's needs.

Pilots have long sought an integrated data-driven, paper-replacement EFB for enroute charting application with global, real-time weather service capture and reporting (Kirby, 2011). These needs were identified during the FliteDeck Pro software application research and design process, featuring coordination with professional pilots and aviation industry leaders (Kirby, 2011; Warren, 2011). Targeted for commercial aircraft operators, the Jeppesen enroute software application supports satellite and Internet connections available through the open design and simple data integration framework of the iPad's application. The digital enroute solution offers value for airline investment committed to in-flight cabin connectivity related to EFB capabilities given efficiencies of fuel planning (Kirby, 2011).

Currently data are communicated between commercial airliners and ground stations with a system called the Aircraft Communications Addressing Reporting System or ACARS (FAA, 2011). The system is a commercial, for profit venture by a firm, AIRINC. ACARS has been in operation since the 1970s and uses very high frequency radio transmissions over ground stations and satellites to relay data to and from the aircraft. The data link message types are rudimentary textual transmissions that can be printed on the aircraft printer. The messages detail weather reports, basic company communications and maintenance status. If one thinks of a 1980s computer screen condensed to a 6" x 6" screen attached to a dot matrix printer, the general technological capability can be realized. ACARS does not have the capability to interface with the iPad, though with modification, could do so.

The FAA is developing a Next Generation Air Transportation system, known as NextGen, for implementation in 2014 upgrading the nation's air traffic control network to 21st century technology. Part of this technology will be a web enabled communication system via satellites and ground stations allowing Internet-like connectivity for the iPad, if aircraft are configured for integration into the NextGen air traffic control system.

Mobile computing as a technology category and the iPad in particular has been revolutionary in the disruption of industries ranging from film photography, digital photography, consumer electronics, music, educational technology and healthcare. In each case a device not designed to specifically compete in a market was found to have applications that allowed users to perform work in a more efficient and effective fashion (Skarzynski & Rufat-Latre, 2011). As applications can be rapidly developed for many computing uses, the role of the iPad has from a consumer of media to a producer and integrator of media enabled by mobile infrastructure. But specific to flight operations, as the opening quote from Weiner (1988) highlights, technology must be coupled to a strategy for application and use with the specific intention of enhancing SA (Endsley, 2010).

iPads as a Disruptive Force to the Current State

Schumpeter (1975) and Christensen (1997) note that throughout history technology creates unintended outcomes. In a classic example, railroads destroyed farming in vicinity of major metropolitan areas because railroads competed for a farmer's lands. Similarly, entry-level black and white transistor-based televisions created a technological basis by which movie theaters were threatened. As the technology in the televisions grew the movie theaters' business model was disrupted given the quality, cost and ease of at-home viewing as compared to attending a movie on site.

Introduction of the iPads into commercial flight operation may be a similarly disruptive moment influencing several decades of safety improvement. CRM is dependent upon creation of a team and shared SA within the cockpit to adequately plan and prioritize threat reduction and error management. Technology plays a key role in this system but as Weiner (1988) notes, an additional piece of technology introduced without rigorous research may unintentionally create disruptive forces, or there may be capabilities of the new technology that are ignored due to the same absence of research and these forces may be negative.

Cockpit Distractions Caused by Technology

Much as with drivers trying to create and read text messages while driving, the introduction of iPads into the cockpit may create a distraction that disrupts cockpit operations. In October 2009, pilots flying a Northwest Aircraft (since merged with Delta Airlines) over flew their intended destination by almost 200-miles while being distracted by a program on the copilot's laptop (National Transportation Safety Board, 2010). Given the fact that 23% of all aircraft accidents can be traced to distractions from task, or task interruption in the cockpit, operators in aviation must be aware that information overload or inappropriate use of technology is a threat to safety (Chou, Madhavan, & Funk, 1996).

A classic example for lessons learned in this area is the American Airlines 757 crash on approach to Cali, Columbia in December of 1995 (Aeronautica Civil of the Republic of Columbia, 1996.) While rushing to prepare for a new approach to the airport the pilots loaded an incorrect navigational point into their flight management computer and then trusted that the autopilot system would bring them to the correct position. At this point they abrogated their control authority and moved to a monitoring position absent completion of a task. Due to further distractions with navigational charts, both pilots allowed their monitoring duties to suffer as well. Unfortunately, due to confusion as to their location and the high terrain surrounding the airport, the flight management system directed the autopilot onto a path that resulted in collision with the mountains, resulting in loss of life and aircraft.

This single example is used to describe the real risks to cockpit operations overly reliant on technology causing distractions. As long as pilots retain control over the mission of the aircraft, they will maintain a higher level of SA than when they move to a monitoring position of a technology. If the automated systems are used, they should be employed as a workload mitigation device and not a placed in a decision-making role. For tasks that are not mission critical, that may be thought of as aircraft or system specific, such as cabin temperature or fuel balancing, delegation to the automated system will not result into a significant safety hazard. Monitoring can be thought of in a time versus risk assessment. If sufficient time exists for human intervention before given a critical situation, delegation to automation will reduce workload, improve effectiveness and minimize fatigue. This does not mean that pilots must at all time maintain physical control of the aircraft, as in manually flying. Rather the control of the technology must be in a dynamic sense and done with conscious reflection. SA ensures the understanding that the technology is responding as the system is designed and the pilots intend.

Statement of the Problem

Technology creates destructive or disruptive outcomes given opportunity for rapid improvement in performance and outputs (Christensen, 1997; Schumpeter, 1975). Technology creates improvements and opportunities but also brings risks and unintended outcomes. A decision to implement a seemingly common device such as an iPad into the cockpit of a commercial airline may offer expanded computing power, more rapid decision making, better fuel conversation and enhanced crew coordination, while building upon a successful culture of safety within airline flight operations. Alternatively, iPads may cause distraction or an inappropriate focus upon technology when basic flying skills are called for. Given the high risk factor of airline operations, systems that are tightly dependent upon one another can create new and unforeseen failure modes (Perrow, 1984).

Tablet computers are entering commercial airliner cockpits absent exploratory research, study on the acceptance of the technology by the pilots, the affect upon cockpit CRM, the consideration of adult education principles to ensure training effectiveness or evaluation of the human system integration for tablet computers specific to the aviation field. The field of applications for iPads and other tablet computers is growing, and questions as to policy or regulation for proper use have not been explored. With varying degrees of pilot user experiences, the technology of tablet computers may not be acceptable to pilots or training in the technology's use may not be effective. Given uncertainties, a flight safety risk may be present if issues of risk management are not properly addressed. There is a possibility that new problems might reside in the human-machine interface where disciplines such as technological innovation, team dynamics, high-risk operations and training meet and interact.

Statement of Purpose

The purpose of this exploratory study was to explore defined parameters of the introduction of tablet computers into the cockpit operations of one commercial airline.

Research questions. The general research question that this study attempted to answer is, "What opportunities and risks lay in the implementation of tablet computers for airline operations?" Specific research questions guided the design of the study:

1. What will be the impact of iPads on the efficiency of flight operations?
2. What will be the impact of iPads on CRM?
3. What will be the impact of iPads on SA?
4. What expanded capabilities might tablet computers bring to flight operations?

Significance of the Study

The result of this study would have both theoretical and practical significance. For the first time in modern commercial aviation, technology is being introduced into flight operations that was not designed specifically for an aviation purpose, and that has the capability to transmit and receive information from outside the standard, formal communication channels. Government aviation human factor scientists within the FAA have not yet researched these capabilities, and there are unidentified risks and opportunities given any technological implementation, especially a safety-critical one such as flight (M. Yeh, personal communication, September 28, 2011). The possibilities that pilots in the cockpit will have greater SA given in-flight Internet connectivity than those in command and control positions, such as air traffic controllers or company managers, create challenges from a system-wide CRM perspective.

As the capabilities of the tablet computer technology expand as well, this exploration may offer significant contributions to efficiencies gained with the enhanced information processing capability within the iPad. If one does a technical comparison, the current flight management computer used in many aircraft such as the Boeing 737 or 757 has a Motorola 68040 processor running at 60MHz, 30Mhz bus clock speed, with 4Mb static RAM and 32Mb for program and database. The iPad's A4 processor runs at 1 GHz while the chip on iPhone 3GS was clocked to 0.6GHz with 1000 times the memory of the 68040. For the first time, the FAA's permission to use iPads while in-flight allows pilots to use technology that exceeds technology designed into the aircraft. The researcher seeks to obtain input from practitioners as to how best implement this quantum capability leap into a complex human-machine system.

Operational Definitions

The FAA (2011) defines flight operations as those periods of aircraft movement from parking brake release until brakes are reset at the point of arrival or aircraft gate. Periods of takeoff and landing are defined by flight for commercial airliners below 10,000 feet as the flight prepares to enter or depart the airport area and are emphasized as being of a high risk to flight safety.

Assumptions

The researcher assumes that the commercial pilots are personally motivated by participation in the topics relevant to the aviation community. The researcher assumes that the respondents will understand the questions asked or seek clarification if needed, and answer the questions honestly. The researcher recognizes his influence given a professional background as a military and commercial pilot, flight and CRM instructor, union membership and experiences in the aviation industry. He acknowledges these biases and will work to limit their effects by regularly consulting with faculty experienced in research to ensure the validity of the interview instruments, coding methods and results.

Delimitations and Limitations

Possible delimitations of this study are:

1. The subjects of this study are commercial pilots with experience using iPads in flight operations. What is true for commercial pilots may not be true for other pilots, such as those from the military, business aviation, general aviation or fields of academia involving aviation.

2. The role of tablet computers in flight and operations is emerging and therefore generalizations may be difficult to form.

3. Application of the iPads in flight may vary based on company, union membership and personal understanding of operating systems.

Internal validity is limited by the qualitative nature of the study. The target population will be small given logistic considerations so as to be able to conduct interviews, as well as the subject population being geographically disbursed.

Chapter 2: Literature Review

This chapter presents literature related to the introduction of disruptive technology into a complex sociotechnical system. The literature regarding the impact of disruptive technologies and then the socioaspects of acceptance, the crew dynamics within the cockpit and the study of adult education and training effectiveness will be reviewed. The intended output of the literature review is an understanding of research of the impact of technology on teams and their SA inside the sociotechnical system. Specifically, literature concerning creative destruction and disruptive innovation will provide understanding of capabilities for technology to create unintended changes to established systems of operation. Technology acceptance by users will review literature on the factors that influence a user's perception on a particular technology's ease of use or usefulness. Technology acceptance will be followed by exploration of CRM and growth of evidence that supports the positive influence CRM has on flight safety by contributing to enhanced SA, particularly technology's role in this process. The risks of both automation surprise and the current study of EFBs will supplement the CRM and SA review. Literature reviewing effective adult education and training will follow. The chapter will conclude with a summary.

Creative Destruction

Schumpeter (1975) developed an economic theory of creative destruction as the means for an industry to survive the type of discontinuous change that typically occurs in a capitalist society because of constant innovation and product change. He emphasized that the creation of new goods and methods of production are inherent in capitalism and the only way to adapt is through the entry of innovative entrepreneurs into the industry, from within or outside established firms. The emergence of entrepreneurs may threaten the existence of monopolies, companies and methods that had previously existed before the change occurred (Schumpeter, 1975). Creative destruction that results from technological discontinuities can create greater upheaval than economic recessions or a drop in demand if mangers do not anticipate the cycles of change by innovating effectively (Anderson & Tushman, 1991).

Schumpeter (1975) created an argument as to why creative destruction is essential for companies and all organizations to survive into the future. The most important part of the leadership vision for an organization is not what remains, but what has been destroyed. Schumpeter's central message was that the process of creative destruction describes the form of competition in capitalism that is capable of dramatic improvements in the quantity and quality of our lives. Without destroying the old ways of doing business, organizations will never successfully create new ones given the lingering cultural attachment to those older methods. Executives must redefine the ways of doing business in order to successfully compete. This is contrary to a more stable and preferred method of incremental innovation in deliberative work process improvement (McCraw, 2007).

Schumpeter (1975) claimed that the new process or product that resulted from a dynamic readjustment of market position, given innovative competition, is more important in understanding capitalism than the "static, standard model of price competition that emphasizes diluted markets as the means to lowering prices, where the goods and the technologies are assumed to be constant" (Basalla, 1988, p. 29). Schumpeter's focus was on the innovation that arises as the destruction of previous work methods occurs and the surviving elements of the organization became the critical engine of economic change as they struggled to survive.

Schumpeter's (1934) writings formalized creative destruction as a process that continuously revolutionizes the economic production processes of the firm because of changing technologies. New technologies prove more effective and efficient destroying the old and creating new approaches to the production of goods and service (Schumpeter, 1975). Schumpeter saw the introduction of new commodities, new technologies, new suppliers, new organizational structure or strategic perspective that commands a decisive cost or qualitative advantage striking at the foundation of the organization's exiting philosophy.

Schumpeter's (1934) conception of the capitalistic and innovative process held that successful entrepreneurs are the creators of new energy within a system that tends towards stagnation due to the size of larger firms. Those larger enterprises, Schumpeter argued, become more conservative, less innovative and fortify themselves within established market positions. To the rising generation of entrepreneurs, the legacy companies represent a barrier to competing successfully in the marketplace. Less efficient established enterprises are unable to rapidly respond to contracting or shifting markets during economic downturns and therefore recessions create opportunities for entrepreneurs once again (Schumpeter, 1934). He explored the phenomenon of creative destruction building the cycle of boom and bust as necessary for economic progress. Economic downturns were seen as periods in which innovative technologies created new growth opportunities (Caballero & Hammour, 1996).

Schumpeter (1934) stated the concept of creative destruction covers the following five cases:

> The first case involves the introduction of a new good that is one with which consumers are not yet familiar or of a new quality of a good. The second, the introduction of a new method of production, that is one not yet tested by experience in the branch of manufacture concerned, which need by no means be founded upon a discovery scientifically new, and can also exist in a new way of handling a commodity commercially. The third deals with the opening of a new market as seen as a market into which the particular branch of manufacture of the country in question has not previously entered, whether or not this market has existed before. The conquest of a new source of supply of raw materials or half-manufactured goods, again irrespective of whether this source already exists or whether it has first to be created is the fourth. The fifth is the carrying out of the new organization of any industry, like the creation of a monopoly position or the breaking up of a monopoly position. (p. 66)

Schumpeter (1934) used the example of railroads to exemplify technology that created dramatic upheavals and intruded into sectors of an economy in which no visible overlap could have been forecast. Railroads were never intended to be a threat to local agriculture, being envisioned as a transportation technology alone. Yet as railroads came together in cities like Chicago and Omaha, local farmers first found their product under priced by the product brought in by railroads and then found the value of their land to be worth more in sale to the railroads as marshaling yards than for the production of crops. Though railroads were seen as transportation, the technology shifted the role of farmers in certain markets destroying some near major cities while positively exploiting others in the distant farmlands in Kansas and Iowa (Anderson, 2002).

Creative Destruction as seen in application and use of the new technology begins to clarify with the parallel and unseen emergence of competition from an unexpected source. Schumpeter (1934) makes it clear that "these new combinations are, as a rule, embodied, as it were, in new firms which generally do not arise out of the old ones but start producing beside them" (p. 66). A discontinuity or creative destruction of the old phenomena begins as the parallel development of new technology enters into work and life in a peculiar, unique form. This uniquely capitalist concept of an innovative application creating unexpected opportunities encourages destruction while at the same time spurring growth.

Abernathy and Clark (1985) studied firms that have found ways to better serve markets gaining economic advantage by application of new technologies. Their work focuses primarily upon introduction of technologies into a new work method that came from outside the firm or industry creating a dramatic shift in technology standards for current competitors. The authors note many of Ford's most innovative practices, such as welding and engine design came from the parallel industry of aviation. Similarly, Henderson and Clark (1990), as well as Utterback (1996), explored the reconfiguration of established processes and industrial systems to join similar components and products together in unique patterns, along with technologies developed for other purposes, providing an innovative good or service. The new technology may have been developed for a completely different purpose but users realize unintended opportunities and the traditional system experiences a radical upheaval. Much as with Schumpeter's railroads, technology developed without the ultimate destructive method in mind is the source for the creative destruction (Davis, Haltiwanger, & Schuh, 1998).

A commonly used technology case study that explores the failure to recognize Schumpeter's theories unfolding has to do with Lotus from the 1990s. The need to carry out creative destruction is never more important or more difficult than when an organization is at the top of its industry. Often, employees share a feeling of having done well and have little desire (with a perception of much to lose) by shifting market or method focus. It is at this time that looking for new opportunities becomes especially critical or otherwise competitors will surpass the company as they take advantage of emerging technologies and markets (Foster & Kaplan, 2001).

Lotus Development Corporation (now part of IBM) held the dominant position the spreadsheet market selling more copies of Lotus 1-2-3 than all its competition combined. Lotus never took advantage of the new technologies offered by the Windows operating system however, and was quickly overwhelmed in the late 90s (McCraw, 2007). Windows was designed for computers, not as a competition for word and spreadsheet processing yet the creation destroyed Lotus' competitive advantage (Davis, Bagozzi, & Warshaw, 1992).

Polaroid had the finest digital technology in 1984, far superior to their competitors at Sony or Fuji. Yet their business model was based upon the sale of instant film. Polaroid gave away the camera so as to capitalize upon future sales of instant film. The digital technology required the camera be sold instead of the film. Polaroid could not force them to creatively destroy that part of their culture, as Schumpeter required (McCraw, 2007). Digital images were originally developed as a way to transfer of office documents with more clarity than facsimiles yet resulted in the destruction of an instant film, an unexpected outcome.

The networked economy means that innovative companies must extend outside to look for new opportunities, the essential message of Schumpeter for innovation. RCA held a dominant position in color television technology, as did Crane in writing paper and Polaroid in instant film. Their failure was not a result of the quality of their technology, but rather the business model, possibly even the mental model, that did not recognize how new technologies fit into the market place and could be a threat to dominance.

Schumpeter's central message was that the process of creative destruction describes the form of competition in capitalism that sustains constant improvement and enhanced vigor in society's commercial life (McCraw, 2007). Current writers have noted a recent Schumpeterian renaissance (DeLong & Summers, 2001; Friedman, 2005; Rosenberg, 2000; Samuelson, 2003; Useem, 1999). In addition, Schumpeter's message of the energizing effect of creative destruction is being researched, rigorously documented, extended and found in application by a group of important business practitioners and academics, including Foster and Kaplan (2001), Christensen, (1997), Christensen and Raynor (2003) along with Zook and Allen (2010).

Disruptive Innovation

A disruptive technology is a technology that changes the competitive ground rules by changing the measures of successful along which firms compete (Danneels, 2004). Customer needs determine which product attributes are valued based upon the utility and benefits of product ownership. Customers can be seen as external to an organization or resident inside organizations along the process stream that creates goods and services. Benefits sought by customers determine which product attributes they value, and different market segments may value different attributes (MacMillan & McGrath, 2000). Competing products offer differing levels of performance on varying dimensions based upon ease of use and usefulness for the consumer. These performance levels of the product, or attribute sets are possible because of the technology embedded in the product. Customer needs or use of the technology determines the definitions of performance success and the basis of competition between product standards. At any given time, a particular technology has performance constraints, which limit the current product's values to a specific customer demographic since each customer may view a unique role for the product.

New products based on a disruptive technology have different attributes than existing products found in use. The performance standards as seen relative to established market products are lower and would be seen as less than desirable by the main customer segment. But for those customers that cannot afford current products, the new entrants have higher performance on attributes valued by isolated and emerging market segments. However, the performance that a technology offers to customers increases over time, and eventually the performance levels offered by a disruptive technology meet or exceed the minimum levels demanded by the mainstream market. Disruptive technologies change the rules of market competition because the technologies introduce an understanding of performance along which products did not previously compete (Christensen, 1997; Christensen et al., 2011; Christensen & Raynor, 2003).

Using disruptive technology, disruptive innovation is business innovation activity that enters noncompetitive areas in which established firms would see reduced profit and increased investment for minimal return. The new technology creates a gap in market performance with competitors by causing a shift in the market place where customers' expectations are reset allowing operational execution of creatively destructive market forces (Christensen, 1997; Christensen & Raynor, 2003). This disruptive type of innovation creates a barrier for competitors. The new entrant requires established competitors to creatively destroy themselves because the level of innovation more affects the organizational strategy more than operational process improvement changes. Disruptive innovation forces firms to face a new and different manner in which business operates. The innovation requires cultural change along with business practice. Competitors must create new strategy, along with a new culture to shift business processes to catch up and close the gap created by the disruptive innovation.

Disruptive innovation describes a process by which a product or service takes root in simple applications in a lower-end market segment. A lower-end market segment is defined as an area in which new consumers originate since they could not participate before given the cost of purchase of existing products (Christensen, Anthony, & Roth, 2004; Christensen et al., 2011). This new product then moves up market relentlessly, eventually replacing established competitors. As an initial mental model to follow the argument development with, consider the path a personal computer has traced since the 1980s. The dominant market leaders in 1980, IBM and Digital Equipment, have been supplanted by the disruptive entry of Apple. At the time, Apple's computer offerings were specifically targeted at schools and classrooms, areas in which IBM and Digital Equipment did not compete. Christensen et al. (2011) note that while IBM has left the personal computer market, and Digital Equipment is not in business, Apple has been able to continuously move products into underserved markets only to gain ascendancy as the technology rapidly improves and outperforms established firms in the marketplace.

There are two types of improvement trajectories in every market. The first type of innovative improvement follows what Christensen and Raynor (2003) describes as a sustaining path. The sustaining path occurs when a firm continuously improves to exceed the current customer expectations. In the computer example one can see the main frames from IBM or the minicomputers from Digital Equipment Corporation as sustaining innovations. Each year the products were incrementally improved so as to create customer satisfaction. But at some point the capability of the systems exceeded the need of the user. Firms that managed data did not need incredible computational power. The infrastructure or user need was now exceeded by the capabilities of the technology. Christensen, Johnson, and Rigby (2002) find that companies that win the battle of sustaining innovation are already clear market leaders. The technologies the market leaders are known for tend to be complicated and expensive, as with the $500,000 IBM mainframe or the $20,000 Digital minicomputer.

A disruptive innovation occurs when a different type of innovation emerges. A disruptive innovation is not a break through improvement and often is not nearly as capable as the sustaining product. But, the disruptive product is affordable, easily applied and useful for a segment of the population that cannot afford the higher market product. The new consumer of the disruptive innovation has a very different definition of quality than what the sustaining market seeks (Christensen et al., 2004; Christensen et al., 2011; Christensen et al., 2002).

With a disruptive innovation the question the innovator must address is what job is the product intended to fulfill? Christensen (1997) emphasizes that consumers buy products, or in his term hires the product, to fulfill a purpose or job. Once a firm understands the job a product is expected to fulfill, opportunities exist to create innovative products that meet the need for the jobs without the cost of a sustaining product. However, just as Schumpeter (1975) warned, this requires the sustaining organization to destroy part of itself so as to shift to the emerging job. Unfortunately for most sustaining companies the disruptive innovation takes root primarily in nonconsumers of the sustaining product and grows from there, as with Apple computers and classrooms (Christensen, 1997).

Returning to the IBM and Digital example, while those firms focused upon sustaining innovation Apple entered the market for computers in schools, a previous nonconsumer of computers. As Apple improved their computers, the new products were capable of some jobs that could previously be done only by IBM or Digital computers at a fraction of the cost. This is the innovator's dilemma according to Christensen (1997). IBM and Digital did exactly as sound managerial practices dictated, they stayed close to their customers and produced capable products yet IBM is now primarily a consulting firm while Digital Equipment has gone out of business.

In this vein of market competition, Adner (2002) focused attention on the demand side of this interplay between markets and technologies specific to competitive advantage for particular firms. He argued for the need to understand the structure of customer demand in order to clarify the market seeking the effects of disruptive technology. Building on Christensen's model, Adner applied understanding of competitive market forces as he characterized the nature and evolution of demand in market segments and identified which kind of market structures disruption occurs within. His work showed that consumers faced with bottom line pressures, such as low margin or heavy infrastructure investments, may be more susceptible to disruptive innovation given the need for lower cost suppliers and processes as compared to the sustaining innovations from established vendors.

Christensen and Raynor (2003) wrote that "disruptive technologies are typically simpler, cheaper, and more reliable and convenient than established technologies" (p. 192). The most recent version of the framework makes a distinction between low end disruptions, which address the low end of an existing value network, and new market disruptions, which create a new value network (Christensen & Raynor, 2003). A new-market disruption is "an innovation that enables a larger population of people who previously lacked the money or skill now to begin buying and using a product" (p. 102). Some of the characteristics of disruptive technology may be universally recognizable, such as performance, whereas other characteristics may be targeted as to innovative application within a business segment. In his review of studies of the impact of technological changes on firms, Chesbrough (2001) noted that Christensen's stream of research has tended to focus on issues of internal validity, and lacks rigor relative to more universal application. Most empirical work on disruptive innovation has been in the form of well documented and thorough single industry case studies, but the extent to which findings from these case studies generalize across industries is lacking. Christensen, Hwang, and Grossman (2009) have done studies of many industries, ranging from hard disk-drive manufacturers to makers of excavators, education and healthcare but the model has not created a predictive capability.

Beliefs, Attitudes, Intentions and Behaviors

Adoption is acceptance of technology at the organizational level. Acceptance is focused upon an individual's beliefs, attitudes, intentions and behaviors towards the technology. While adoption deals with the surrounding culture, acceptance is seen with the individual within the larger system of people, processes and technology (Dillon, 2001).

Fishbein and Ajzen (1975) proposed a framework to describe and predict human behavior forming a causal structure of beliefs, attitudes, intentions and behaviors. Beliefs were defined as the information and opinion the individual developed with relationship to the object of acceptance. The term cognition is used in place of beliefs at points within the literature. Attitude represents favorable or unfavorable feelings developed upon evaluation of the object. Intentions refer to an individual's intention to perform the behavior and are referred to as conation by Fishbein and Ajzen. Behavior is the observed action that results from the decision to use the object of the study.

These four categories result in an individual's attitude toward a particular object determined by probabilities of beliefs regarding the utility of the object. The probabilities are determined as results of an individual's intentions to perform the behavior. As an example, one may consider a new office technology to be convenient and easily accessed, however the visual clarity of the output is of poor quality. The results of these positive and negative observations lead the user to form an attitude towards the new office system. The attitude towards the system influences the user's intention to use and to recommend use to colleagues. These intentions eventually impact user behavior as to use of the system.

Given the initial constructs of beliefs, attitudes, intentions and behaviors much additional research has been done to analyze similar constructs with a specific focus on information technology and computers. Ajzen and Fishbein (1980) and Ajzen (1991) developed the theory of reasoned action (TRA) from which Davis (1986) developed the original technology acceptance model (TAM), which is a predictive model of individual acceptance of technology used in order to accomplish work. Additionally, social elements have been taken into account, as seen in factors in the surrounding environment, in development of the theory of planned behavior (TPB) and social cognitive theory (SCT; Venkatesh, Morris, Davis, & Davis, 2003).

Theory of Reasoned Action

TRA was developed by Fishbein and Ajzen (1975) to predict human behaviors using beliefs, attitudes, intentions and behaviors as a framework. TRA was developed to model an individual's beliefs as to results of performing a particular behavior as an impact upon a person's attitude towards performing that behavior. Since Fishbein and Ajzen and Ajzen (1991) determined that attitude towards behavior had a stronger impact than attitude toward the activity or object, TRA defined attitude as the individual's positive or negative feelings regarding the behavior. Attitude was seen to determine an individual's intention to perform that behavior. The greater the degree of intention led Ajzen and Fishbein (1980) to note the greater the likelihood that the individual will perform the behavior.

TRA proposed that an intention to perform an action was also influenced by the subjective norm as well as the attitude of the individual. Subjective norms were defined as individual perception of the importance of the behavior that should be performed and addressed the influences from the individual's social environment (Fishbein & Ajzen, 1975). Subjective norms were described as the individual's perceptions of what those people that the individual deems significant thought about performing or not performing the behavior.

TRA has gained wide acceptance from social scientists in order to explain and predict human behavior in specific situations. TRA has been validated in research regarding consumer and health behavior (Hale, Householder, & Greene, 2003; Holden & Ben-Tzion, 2010). Lu, Hsu, and Hsu (2005) noted that the model is able to predict consumer intentions and behaviors but also warn that intentions may be influenced by time, events and other environmental forces that have no relationship to the individual's acceptance or rejection process.

With regard to technology and computers, Davis, Bagozzi, and Warshaw (1989) and Shephard, Hartwick, and Warshaw (1988) suggested that subjective norms contribute insignificantly to behavior. Further only behaviors within volitional control, or those that and individual may exercise interest in, should be applied within the scope of the TRA (Ajzen, 1991; Hale et al., 2003; Shephard et al., 1988). Those instances in which an individual's behavior may be involuntary, habitual or unconscious may not apply.

Theory of Planned Behavior

With the TPB, Ajzen (1991) created an extension of the TRA in order to address the original model's limitations in dealing with behaviors over which people have incomplete volitional control because of external factors, lack of awareness or resource inadequacies. The TPB suggests that along with attitudinal and normative influence upon individuals, a third element, perceived behavioral control, also influences an individual's behavioral intentions and actual behavior. A condition, over which the individual does not have full control, or that imposed by the environment, are accounted for in the TPB as additional factors were not included in the TRA (Ajzen, 1991).

Three considerations guided human action within the TPB framework according to Ajzen (1991). The first consideration was the utility of the behavior as an outcome and the evaluation as to the likelihood of the utility. The second factor considered the individual's normative expectations of the reaction others the individual respects as to approval or disapproval. The second factor addressed the reaction of other's to the individual's use. The third factor dealt with resources and impediments. The individual considered if resources and opportunities were possessed so as to counter anticipated obstacles or impediments in performing the considered behavior.

When treated from a systems perspective, behavioral beliefs produced a favorable or unfavorable attitude toward the behavior. The normative beliefs resulted in perceived social pressure from other's who carried significant influence on the individual or subjective norms of the team, society or organization. The control beliefs give rise to person's control of their behavior (Ajzen, 1991).

Some researchers noted the TPB to be lacking in the creation of specific cause and effect between perception and acceptance as seen in behavior. The TRA and the TPB assumed proximity between intention and behavior within specific situations suggesting understanding of the situational dynamics was a significant factor (Foxall, 1997). As Eagly and Chaiken (1993) wrote, the assumption of a causal link between an individual's behavioral choice and intention presumed that people decided to engage in behavior because the individual's believed success likely. Second, the means of measurement of the theory was made problematic by the measuring of individual behavioral choice directly, as opposed to recording control beliefs (Davies, Foxall, & Pallister, 2002). The literature emphasized the theory introduced only one new variable when there was evidence from additional research that other factors added predictive power over and above the measures formally incorporated in the TPB. For example, Manstead and Parker (as cited in Davies et al., 2002) argued that personal norms and affective evaluation of behavior may have accounted for variance in behavioral intentions that were too complex to be accounted for by the TPB as configured at the time. Ajzen (1991) himself described the model as being a candidate for additional predictors if research showed that a significant proportion of the variance in intention or behavior was not accounted for after the theory's current variables had been accounted for.

Technology Acceptance Model

Although many models have been used to explain acceptance and predict use of a technological system, the TAM has been the most tested and used (Venkatesh, 2000). The TAM specifically described technology use behavior across a broad spectrum of applications and user types (Davis, 1986; Davis et al., 1989). TAM has proven validity and reliability for the understanding of information technology usefulness and ease of use which in turn act as predictors as to an individual's attitude and intention to use the technology (Chau, 1996; Chau & Hu, 2002; Davis et al., 1989; Dillon, 2001; Igbaria, Parasuraman, & Baroudi, 1996; Lu et al., 2005; Mathieson, 1991; Szajna, 1994; Venkatesh, 2000; Venkatesh & Davis, 1996; Yi, Jackson, Park, & Probst, 2006; Yousafzai, Foxall, & Pallster, 2007).

Davis (1986) modified the belief, attitude, intention and behavior relationship of the TRA to develop the TAM. The TAM suggested that user motivation could be explained by three elements, the perceived usefulness (PU) of the technology, the perceived ease of use (PEU) and the user's attitude (A) towards using the technology.

These three elements develop behavior intention (BI) to use the system and resulted in the actual system use or behavior (Davis, 1986; Davis et al., 1989; Venkatesh et al., 2003). The attitude of the user towards the technology in question was found to be a major determinant as to whether the user will actually apply or reject the technology. Both PU and PEU influenced the attitude of the user.

PU was defined as the degree to which an individual believed that using a particular system would enhance his or hers job performance (Davis et al., 1989). PEU was the degree to which and individual believed that using a particular system would be free from physical or mental effort. One purpose of the TAM has been to serve as a starting point for examining the impact that external variables can have on behavioral intentions (Davis et al., 1989). Venkatesh and Davis (1996) suggested attitude does not play as significant a role as PU and PEU determine the intention to use technology. Venkatesh (2000) moved towards strategic understanding as to relationships with the larger organization as to impact upon the usability and usefulness of the technology. He created modifications to the original model to include the four determinants of computer self-efficacy, perception of external control, anxiety towards technology and computer playfulness. He also considered two adjustment-based factors that develop with experience, the perceived enjoyment and objective usefulness. Davis et al. (1989) and Chau (1996) suggested external variables that represent individual differences, along with situational constraints and managerial behavior, training effectiveness and user support are important determinants on PU and PEU. Davis et al. and Venkatesh indicated future investigations of TAM implementations of the external variables being needed in order to create understanding of the environment upon acceptance and use.

TAM has become well established as a robust and powerful model for predicting user acceptance of technology. TAM has been found to have applicability to technology acceptance across a diverse user population and wide range of systems. The model is operationally applicable to work situations and has a strong statistical base with well-researched and validated psychometric measurement scales. Replication shows that results hold across countries, industries and time spans. The results have yielded strong empirical support as regards to mobile computing, healthcare technology, financial services, online banking, online education, technology in the classroom for teachers Web-based search engines and business analytic software (Chau, 1996; Djamsbi, Dishaw, & Strong, 2010; Holden & Ben-Tzion, 2010; Igbaria et al., 1996; Mathieson, 1991; Szajna, 1994; Taylor & Todd, 1995; Venkatesh et al., 2003; Yousafzai et al., 2007).

Mathieson (1991) critiqued TAM because there is no supporting research as to how PEU and PU can be manipulated so as to ensure technology acceptance. Additionally the critique was extended to require a better measure of output quality and explication so as to modify potential behavior.

Social Cognitive Theory and Self-Efficacy

Originating from SCT as proposed by Bandura (1986), self-efficacy was defined as a person's perception of how easy or difficult a behavior was to execute. Self-efficacy referred to an individual's beliefs about their own capabilities to perform actions at an acceptable level exercising influence and control over events that impact their lives. In the arena of information systems and technology, self-efficacy was seen as important in understanding individual responses to, and acceptance of, technology as part of a work system. Schwarzer (1992) stated that self-efficacy is the belief that one can perform a new or unique task, or handle adversity and negative responses in a variety of situations. Moreover, self-efficacy can affect human performance in terms of choices regarding behavior, motivation, biases, mental models and responses, and the idea of personal purpose and relevancy.

Given that one of the most powerful theories of human behavior is SCT (Bandura, 1986), Compeau and Higgins (1995) applied and extended SCT to the context of computer use by individuals. Compeau and Higgins' model studied computer use but the nature of the model and the underlying theory allowed Venkatesh et al. (2003) to extend the concept to acceptance and application of information technology in general. The original model of Compeau and Higgins used usage as a dependent variable but in keeping with the intent of predicting individual acceptance, Venkatesh et al. examined the predictive validity of the model in the context of intention and use to allow a fair comparison of the acceptance models.

When applied to technology, Compeau and Higgins (1995), along with Venkatesh et al. (2003), maintained the model examines an individual's outcome expectations or the performance expectations of technology use as seen with job-related outcomes. The model also considered the role of personal esteem related to the use of the technology as viewed from the perspective of self-accomplishment. Self-efficacy was considered as to an individual's perception as to readiness to accomplish the task or employ the technology. Considerations as affection and anxiety were included in the model. Affection was seen as in a person's likelihood to find enjoyment in the use of the technology and anxiety defined as the emotional behaviors that are anticipated with the use of technology.

TAM2

A recognized limitation of the TAM was that the model did not account for external factors that impeded or prevented an individual from adopting a particular information technology or system (Taylor & Todd, 1995; Venkatesh & Davis, 1996). Research into improvements for TAM has attempted to add user resources, perceived support and constraints. These included subjective norms, voluntariness of use, relevance to task performance, quality of the output and results that demonstrate alignment with job functions (Mathieson, 1991). Taylor and Todd (1995) described external, independent variables as system design of the technology, training, support and decision-maker characteristics of the managerial staff implementing the technology. By adding these factors researchers suggested greater robustness of the model, as seen as improvement in the models predictive capability, would be achieved. Venkatesh et al. (2003) wrote that a statistically significant improvement in the accuracy of prediction of acceptance from 17% to 42% could be achieved with inclusion of the external factors that TAM2 identifies.

Unified Theory of Acceptance and Use of Technology

In composing the unified theory of acceptance and use of technology (UTAUT), Venkatesh et al. (2003) proposed a unified model integrating acceptance determinants drawn from several previous models. The result of the discussion and debate over the best technology acceptance tool resulted in eight models that received support in recent literature. Each model was a variation upon the previously noted underlying models of TAM, TAM2, SCT or TRA. Using past historical data, Venkatesh et al. attempted to validate the UTAUT by testing with historical data from previous TAM researchers, while including additional considerations from SCT and TPB in a new model development. Prior to the existence of the UTAUT, TAM was the most widely utilized theory to study technology acceptance within the information systems discipline (Dwivedi, Williams, & Lal, 2008; Venkatesh et al., 2003).

According to UTAUT, intention to use technology can be predicated by three antecedents to the use. The first is performance expectancy, the second the effort expectancy and the third is social influence. As a consequence, intention to use technology then exerts influence on actual behavior toward technology adoption with facilitating conditions as to the use of technology considered. Performance expectancy is defined as the degree to which an individual believes that using the system will help him or her realize enhanced performance with work processes. The concept of performance expectancy has been considered the most powerful concept for explaining the intention to use a technology regardless of the type of environments, described as mandatory or voluntary.

The UTAUT model infers that the three direct variables of performance expectancy, effort expectancy, and social influence will determine the behavioral intent of an individual to use technology and a direct determinant of usage behavior given facilitating conditions (Dwivedi et al., 2008; Venkatesh et al., 2003; Williams, Dwivedi, Lal, & Schwarz, 2009). The model integrated four moderating factors previous models did not. The moderating factors were gender, age, experience, and voluntariness or the choice an individual had in the use of the technology. The moderating factors had varying influence upon the primary constructs of ease of use and usefulness. In summary, the UTAUT model condensed the 32 variables found in eight existing models into four main effects and four moderating factors. The main effects or components are composed of Performance Expectancy (PE), Effort Expectancy (EE), Social Influence (SI) and Facilitating Conditions (FC).

PE was defined as the degree an individual believes that using the system will help attain gains in performance. EE was the degree of work, or absence or work, associated with the use of the system. SI was the degree an individual perceived people of significance believed that the model should be used. FC was the degree the individual believes that and organizational and technical infrastructure exists to support the system.

UTAUT has four moderators that affect the components. The moderators were gender, age, experience and voluntariness. The moderating factors influence the four components. Gender and age influenced performance expectancy, effort expectancy and social influence. Age and experience moderated the facilitating conditions. Experience moderated effort expectancy, social influence and facilitating conditions. Voluntariness of use moderated the effect of social influence. These combinations of the components and moderating factors increased the predictive accuracy of use to 70% as compared to 40% for previous TAM research, according to Venkatesh et al. (2003).

CRM Background and Literature

CRM is a process to develop team SA, improve decision making and contribute to the safe execution of flight using all available resources. CRM was developed from research conducted by the United States' military during World War Two and originally called Cockpit Resource Management in recognition that as aircraft had become mechanically more reliable, the majority of aircraft accidents became attributable to pilot errors and specifically errors in pilots' judgment (Murray & Maurino, 2010).

Since 1980, though travel by commercial airlines in the United States remains by far the safest method available, 80% of all commercial aircraft accidents remain the result of human error (Baker et al., 2008). A series of fatal commercial aircraft accidents in the late 1970s resulted in the loss of over a thousand lives. Each mishap was attributed to human error, particularly errors in the management of the human resources within the cockpit such as poor communication, a lack of teamwork and absent leadership from the Captains in command. The recognition of the significance of flight crew errors resulted in extensive research beginning in 1979 and identified types of pilot performance in respect to technical and attitudinal attributes that ensure pilot and aircraft safety (Cooper, White, & Lauber, 1980) Proper application of those types of pilot performance were theorized to minimize and mitigate the impact of pilot error. The initial research was conducted at NASA but has since spread through industry and academia.

CRM has been defined in several different ways since the initial introduction in 1979. General definitions in literature agree that CRM is the development of team work, attitudes, communication skills, leadership behavior and contribute to SA so as to execute safe and efficient flight operations (Brannick, Prince, Prince, & Salas, 2005; Foushee & Helmreich, 1988; Helmreich, Merritt, & Whilhelm, 1999; Salas, Fowlkes, Stout, Milanovich, & Prince, 1999). The literature emphasizes training and education in CRM and the theoretical frameworks of teamwork, leadership, risk analysis and SA as methods to foster behavioral skills conducive to safe flight operations. The FAA defines CRM as:

> The effective use of all available resources: human resources, hardware, and information. Other groups routinely working with the cockpit crew, who are involved in decisions required to operate a flight safely, are also essential participants in an effective CRM process. These groups include but are not limited to:

(a) Aircraft dispatchers.

(b) Flight attendants.

(c) Maintenance personnel.

(d) Air traffic controllers. (FAA, 2004, p. 187)

CRM training is one way of minimizing risk by application of study and preparation regarding the human-machine interface and accompanying interpersonal activities in flight. The study areas include team building and maintenance, information transfer, problem solving, decision making, maintaining SA, and dealing with automated systems. CRM training contains three tiers or phases: initial indoctrination and awareness, recurrent practice and feedback, and continual reinforcement (FAA, 2004).

Salas et al. (2010) described CRM as a set of instructional strategies designed to improve the behavior, cognition and attitudes that compose team work in order to achieve mutual goals meeting the operational demands of the outside environment ensuring safe flight execution.

The first generation of CRM began at United Airlines with a focus upon leadership as developed by the Blake and Mouton Grid (Foushee & Helmreich, 1988). Blake and Mouton (1982) maintained that leadership was choice dependent. One chooses a style best suited to balancing task and behaviors. In the Blake-Mouton Grid if the X-axis is an increasing concern for task accomplishment and the Y-axis is an increasing concern for people, the high right corner would be known as 9,9 (9 on the X and 9 on the Y). This is the optimum position in Blake and Mouton's opinion showing the ultimate in team management with a determined and participative style. The 1,1 position shows neither concern for people or task, but is known as the impoverished position. In the upper left position, at 1,9, the country club manager exits showing great concern for people but little for work. The lower right is the dictatorial or autocratic efficiency expert, showing a great deal of emphasis on the job but none for the human element. In the center, at point 5,5, the middle of the road leaders exists. These seek only minimum acceptable results for both.

Blake and Mouton (1982) emphasize that one's position on the grid is attitudinal and conceptual, selectable by the leader with disciplined focus. This is a broad framework but one based on two variables. Leaders will have a dominant style and must understand that under pressure, when the chance for a disciplined effort is reduced, a secondary style will emerge. While this structure is easy to understand and very broad, it is also not the ultimate single source answer given the variable responses under pressure.

Using Blake and Mouton, the training at United was developed as a result of lessons learned from a crash investigation of a 1978 mishap at the Portland International Airport (Helmreich et al., 1999). The causal factors of the crash were discovered to be poor cockpit team dynamics involving an overbearing, dictatorial Captain coupled with a Flight Officer and Engineer that did not effectively assert their observations as to the developing unsafe situation. The initial CRM consisted of seminar forums looking at managerial issues and resource concerns from a Captain's perspective within the cockpit emphasizing behaviors and attitudes that contributed to moving the Captain's behavior to a 9,9 on the Blake Mouton Grid (Foushee, 1984). Much of the syllabus was dedicated to influencing Captains to listen to First Officers and Engineers, soliciting their opinions and seeking advice on unfolding flight operations. This approach was seen as a counter to the traditional, command and control, militaristic decision-making process found in the industry at that time. Resistance was noted in the literature as the Captains responded by viewing CRM as an assault upon their authority (Foushee, 1984; Helmreich et al., 1999; Salas et al., 2010). Yearly recurrent training began in the industry as some evidence became available that safety data was improving as a result of the influences of CRM.

In 1986, NASA began studying the integration of CRM into all flight training (Orlady & Foushee, 1987). Additional research sponsored and pioneered by Delta Airlines moved the focus from the Captain's leader behavior to leadership within a team. This change in emphasis was the point the name shifted from cockpit resource management to CRM (Byrnes & Black, 1993; Helmreich et al., 1999). CRM research began to study line flight operations and sought recurring data linking superior team integration with improved safety and performance. Specific results showed distributed decision-making strategies, participative and coaching leadership behaviors, high SA and stress management to be strong contributors to safer operations. Training and education exercises continued to be modular and absent integration with the technical flying skills portion of pilot preparation. The literature noted that the training was developed by industrial psychologists and absent input from operational pilots. There were noted instances that pilots resisted CRM because of the jargon and scientific tone of the CRM language that was absent relevance to the operational aspects of aviation. The training was at times condemned as irrelevant by research studies because of what respondents viewed as training absent application (Birnback & Longridge, 1993; Byrnes & Black, 1993; Flin, O'Connor, & Mearnes, 2002; Helmreich et al., 1999).

Emphasis from research shifted to a more holistic perspective of the aircraft as part of a larger system composed of company and institutional resources (Birnback &

Longridge, 1993). Integration of flight attendants, union experts, dispatchers, operations managers, flight controllers, manufacturer representatives and maintenance personnel into flight decision-making methods began. Many air carriers began integrated CRM training involving all members of the organization. Simultaneously the FAA, in conjunction with United Airlines, integrated CRM training and qualification programs into the flight-training syllabus for pilots. CRM became part of the flight system rather than executed as a separate training activity. CRM was embedded in procedures, practices and the flight discipline in the effort to ensure relevancy to the training (Flin et al., 2002; Helmreich et al., 1999; Merritt & Helmreich, 2007; Salas et al., 2010). The program of integration was and is known as the Advanced Qualification Program (AQP), is voluntary and allows each airline to modify training as needed to integrate CRM into Line Oriented Flight Training (LOFT). LOFT allows airlines to create customized training using FAA standards as learning outcomes, instead of syllabus steps. Rather than train to simple flight dynamics, pilots at participating airlines fly actual flight profiles with FAA-approved integration of realistic flight scenarios, such as emergency mechanical problems, extreme weather shifts, as well as security problems, creating opportunities to apply CRM principles under observation from trained instructors and facilitators treating the flight system as part of the integrated whole. The integration of CRM with flight training is commonly referred to as fourth generation CRM (Helmreich et al., 1999; Murray & Maurino, 2010).

Research on human error in complex sociotechnical systems created understanding that inside the complex systems human error by operators was seen to be unavoidable and often attributable to managerial and engineering decisions beyond the control of the operators (Perrow, 1984; Reasons, 1997). The research looked at the human errors involved in scenarios such as the Three Miles Island nuclear mishap and the Challenger explosion. These theories influenced the direction CRM has taken since the fourth generation.

Researchers of fifth generation CRM view aircrew error as an unavoidable part of flight operations given human fallibility and complexity of aircraft systems (Flin, O'Connor, & Crichton, 2008; Flin et al., 2002). Though the certainty of errors is accepted, CRM now seeks to minimize their impact by recognition and correction, followed by containment if necessary, at the earliest possible point within the error chain. Studies sponsored by Continental Airlines and conducted by researchers from the University of Texas placed trained observers on the flight deck of airliners as part of a program called Line Operations Safety Audit (LOSA) in order to collect data as to the occurrence of error as well as pilot methods for recognition, mitigation and containment (Helmreich et al., 1999; Jones & Tesmer, 1999; Klinect, Whilhelm, & Helmreich, 2001). Using desensitized data removing pilot names, errors were reviewed and application of specific, repeated flight crew responses created patterns for recognition, coordination, decision making and response that pilots had naturally developed over the years almost in anticipation of human-error research. Countermeasures followed standard processes within well-coordinated cockpits and then employed effective CRM teamwork, leadership, communication and decision-making processes from an entire flight system perspective. The defenses created error avoidance followed by rapid trapping of incipient error and then mitigation, if the errors could not be trapped (Helmreich et al., 1999).

As part of the research results, the responses from well-coordinated aircrew practicing strong CRM principles demonstrated the value of threat recognition. Threats are those elements outside the aircraft and beyond the scope of pilots' control. The recognition that good cockpit crews had intuitively and successfully dealt with the threats for decades resulted in a formal articulation of the process and the combined research results were called Threat and Error Management or TEM (Helmreich et al., 1999). TEM became an addition to CRM training inside the LOFT simulations as well as line operations emphasizing enhanced SA to both the environment and internal interactions of the human-machine systems.

The 21st century has brought CRM research that has focused upon the integration of Hofstede's (1980) research on national culture as an influence to team and interpersonal dynamics. The literature reveals a replication of Hofstede's results inside the cockpit and also confirms that national culture exerts an influence upon CRM behaviors and has more of an impact than the professional culture of pilots (Merritt & Helmreich, 2007; Murray & Maurino, 2010).

Overall, CRM training, education and implementation has been viewed as highly beneficial to the aviation industry. Flin et al. (2008) examined evaluations of CRM research to determine the level of effectiveness that CRM has upon individual, team and larger organizational outcomes. The results found that CRM had a significant impact on attitudes and behaviors of those involved with CRM, but a medium impact on knowledge of CRM itself. Additional research is needed to address the actual correlation between CRM and accident rates in companies and the United States flight system (Salas, Wilson, Burke, & Wightman, 2006). The same research also noted further emphasis on a connection between CRM and airline profitability should be explored. The role of measurement as to effective CRM has yet to be assessed as to accuracy and applicability.

CRM has moved from the aviation industry to a variety of other professions (Salas et al., 2010). CRM is commonly taught to hospital operating room teams, nuclear reactor operators, elite military units, firefighters, and police officers and inside educational systems. Military aviation has followed suit across the services as has NASA, general aviation, business aviation and rotary wing flight departments.

EFBs: Current Literature, Evaluation and Hazards

EFBs are defined as small, customizable information management devices that aid pilots during flight operations in order to enhance effectiveness and efficiency (Chandra, Yeh, Riley, & Mangold, 2003). EFBs are designed to replace paper-based manuals and charts with digital versions in order to enhance accuracy, readability, reduce weight resulting in fuel savings with better efficiency in those operations. The initial flights tests of EFBs began in 1999 using laptop computers to calculate flight performance data and view airline documents for navigation and procedures. The laptops were used to replace Pilot Operating Handbooks and Flight Operations manuals. Over the next four years additional capabilities such as electronic maps, surface depictions, runway layouts and even cargo hold surveillance cameras were developed (Carey & Michaels, 2002; Chandra & Yeh, 2006). Though cost is more than a traditional laptop because of the customizable software the EFBs are an attractive alternative for some operations because of the customizable capabilities. The cost of the laptops did not reach a point to which the major airlines implemented the systems until the tablet computers reduced cost to less than $500.

EFB's were evaluated in literature by the Volpe Center, the research arm of the Department of Transportation, in regard to usability, human factors considerations and general systems considerations (Chandra & Yeh, 2006). The EFBs were compared to traditional methods of operation, which were paper charts and manuals as well as a comparison of a variety of EFBs developed by different vendors. The evaluations sought to create a tool that could be used by both regulatory evaluators and technical design firms (Chandra, Yeh, & Riley, 2010). The Federal Aviation Advisory Circular (AC) 120-76A had approved a streamlined field approval process for EFBs and the efforts by Chandra et al. (2010) were designed to streamline the evaluation from 200 survey questions to a more manageable tool that could be completed during flight test operations under 4 hours. The intended users were air transportation pilots seeking evaluation from a flight operations perspective and FAA field evaluators conducting practical usability evaluations.

The literature reveals that the need for evaluation was identified by Chandra et al. (2003), but a useful tool that recognized the interplay between portable computing technology and human operators was presented by Chandra et al. (2010). The tool was created to identify major system weaknesses in design. Specifically noted is that in tests, the intended pilot operators from major air carriers were not involved to solicit user input, instead general aviation pilots and human factor scientists were used to provide evaluation of the assessment tool. The elements of the assessment tool from Chandra et al. (2010) were offered in 5-point Likert scale format and listed as:

- Hardware Considerations
    - Physical ease of use—input devices and display, accessibility of controls

    - Labels and controls
    - Lighting issues (day vs. night use)—brightness adjustment, illumination of labels
    - Amount of feedback, potential for errors
    - Software considerations
    - Symbols and graphical icons
    - Clarity of intended meaning, confusability
    - Legibility and distinctiveness
- Formatting/Layout
    - Fonts (size, style, case, spacing)
    - Arrangement of information on the display—consistency with user expectations and internal logic
- Interaction (accessing functions and options)
    - Home pages and ease of movement between pages
    - Number of inputs to complete a task
    - Ease of accessing functions and options
    - Feedback (system state, alerts, modes, etc.)
    - Responsiveness
    - Intuitive logic
- Error handling and prevention
    - Susceptibility to error (mode errors, selection errors, data entry errors, reading errors, etc.)
    - Correcting errors (e.g., cancel, clear, undo)
    - Error messages

- Multiple Applications
    - Consistency and compatibility across applications
    - Identifying current position within system
    - Ease of switching between applications
- Automation (if any)
    - Is there enough? Too much?
    - Is it disruptive/supportive? Predictable? User control over automation? (e.g., manual override)
- General
    - Consistency of controls/elements; are they distinctive where appropriate?
    - Visual, audio, and tactile characteristics
    - Use of color (especially red and amber) and color coding
    - Amount of feedback (system state, alerts, modes, etc.)
    - Clarity and consistency of language, terms, and abbreviations
    - End-user customization (if any)
- Workload
    - Problem areas

Research by Chandra and Kendra (2009) has evaluated the impact of EFBs upon aircraft accidents and reported flight safety violations between 1995 and 2009. The authors searched databases held by NASA and the National Transportation Safety Board (NTSB) of self-reported pilot violations and near violations of prescribed rules and policies in which EFBs were a contributing or primary factor. Sixty-seven violations were discovered all dealing with incorrect data management related to airport layout depictions causing taxi violations, takeoff distance and speed inaccuracies or miscalculations and landing distance calculation problems. Thirty-seven of the 67 reports were related to airline transportation violations while the others dealt with general or business aviation. There was a high of 15 reported in 2006 while the number of submitted reports has dropped to only a few since. The authors suspect that this may be due to the financially constricted market airlines are currently operating within. In 56 of the 67 cases studied, the typical scenario involved one crewmember becoming distracted because of confusing interactions with the technology and a subsequent breakdown in crew coordination.

Chandra and Kendra (2009) reviewed two accidents that have involved misuse of EFBs. The first was a 1995 crash of a FEDEX MD-11 because the First Office improperly calculated the landing speed due to improper entry into the EFB calculations. Though not the primary cause, the higher than needed approach speed contributed to the Captain's over control of the aircraft during landing and resulted in the crash of the aircraft, though the two pilots and three passengers were not injured.

Of far more serious outcomes, a Southwest Airlines 737-700 slid off the runway at Midway Airport as a result of an excessively high approach speed during a snowstorm. The First Officer had entered an 8-knot tailwind component into the EFB for landing calculations but erroneously exceeded the 5-knot tailwind limit for the airframe. The EFB was programmed to not exceed 5 knots and used that amount for the landing calculations. Given the slippery surface on the runway due to snow, a poor landing by the Captain and some malfunctioning equipment the aircraft slid off the runway and impacted six cars, killing one person.

In 2009, an Emirates Airbus A-340 failed to takeoff properly from Melbourne Australia (Creedy, 2009). An improper, excessively low weight had been entered into the EFB and the resultant airspeed provided for pilot takeoff rotation was almost 20 knots below that needed. As the pilot attempted to rotate the lift was not sufficient for takeoff causing the tail to drag along the ground and impact with lighting off the end of the runway. The aircraft eventually made it airborne and was able to return for a safe landing at Melbourne without loss of life.

SA

SA was first recognized as relevant to the field of military aviation during the First World War. The awareness of environment, position, threats and opportunities a pilot develops and experiences was first known as the "ace factor" and proven in practice to be an essential element to success in aerial fighting (Spick, 1988; Watts, 1996). The study of SA has spread since the Second World War to include perceptions at the individual and team level with respect to the meaning of events within time and space, relevance to mission or purpose along with a projection of possibilities into a future state (Endsley, 1995, 2010). Commercial aviation, air traffic controllers, other branches within the military, fire fighters, police units and operating room teams have all begun exploring the application and meaning of SA to their professions (Endsley 2010). SA is related and integral to CRM in a systemic way being an input to; process and output from intelligent CRM while simultaneously relying upon CRM to enhance the level of SA. If CRM captures the necessary team dynamics, SA is symbiotically improving CRM while simultaneously being improved by CRM (Dostal, 2007; Endsley, 1995).

The literature emphasizes the importance of SA in creating CRM that contributes to execution of safe flight. In multidisciplinary settings SA information is affected by abilities of individual members, their interaction with other team members, and the environment in which they collaborate. SA is one of the most prominent research topics in the field of aviation psychology and aviation training. The term has been adopted to describe the processes of attention, perception and projection that form a pilot's mental model of the current and future situation (Adams, Tenney, & Pew, 1995; Endsley, 1995). SA researchers have focused on the attempt to measure a pilot's knowledge or awareness of a current situation as compared to the actual situation at a given moment in time. The approach of trying to quantify SA has been attempted, but literature also emphasizes the importance of the process by which SA is obtained by pilots (Endsley, 2010).

The literature reveals a variety of definitions for SA. Endsley's (1995) definition that SA is the perception of environmental elements bounded by space and time coupled with the comprehension of their meaning and projection as to status in a near-future state is commonly used. Endsley then developed three levels of SA to create a hierarchy to SA proficiency for pilots. Level One SA focuses upon perception, which involves perceiving the status, attributes and dynamics of relevant elements found in the environment. Pilots must accurately perceive information about their aircraft as to performance measured by speed, altitude and attitude, weather, systems in the aircraft, systems outside the aircraft such as air traffic control and airport status and company issues, as well as the interpersonal relationships within the aircraft and cockpit.

Level Two SA synthesizes the information endowing perceptions with meaning as to relevancy and purpose. Understanding of the elements allows pilots to assess impact creating a holistic picture of the systems and status of a flight relative to the status of the larger system. Level Three SA moves the mental process to a projection. Trends discerned in the synthesis of perceptions are studied and create a predicted understanding of a future state. Future scenarios are mentally played out as the systems as a whole interacts in an unfolding mental display (Endsley, 1995, 2010).

Sarter and Woods (1991) described SA as one's accessibility to a complete and clear situational representation which is being constantly revised based upon observations, assessments based on performance standards and learning. Flin et al. (2008) viewed SA as a state achieved by a stakeholder when both quantitative and qualitative status are understood via information exchange patterns to meet configurations determined to fit a conceived role. Dominguez, Vidulich, Vogel, and McMillian (1994) described SA directing further perception after establishing a coherent mental picture gained by a continuous extraction of information from the environment coupled with integration into previous knowledge. Adam (1993) and Moray (2004) simplified the work by seeing SA as recognition of what is going on coupled with knowledge as to the utility of the information. Dostal (2007) saw SA as a clear and relevant mental picture of the tactical situation, including environmental factors and system disposition. Fracker (1991) coupled new information with working memory and knowledge to develop a composite picture of a situation along with a future state supporting decisions as appropriate courses of action. Each of these sources separated SA from the decision-making process, though essential to the making of good decisions. Each researcher supported the understanding of SA as a continuous process of adaptation based upon comprehension of meaning. Decision making is related though not part of the SA literature, in a sense seen as the next step in the cognitive process (Endsley, 2010).

SA is developed in team form when multiple system elements come together. A single-piloted airplane working with air traffic control creates an opportunity for a shared awareness of the situation as does a multipiloted airline crew working with controllers. Salas, Dickinson, Converse, and Tannenbaum (1992) described a team as any interrelated effort between two or more people towards a specific mission, goal or purpose with assigned, specific roles and a limited span of time to participate within the effort. Endsley (1995) coupled SA into teamwork by noting Team SA is achieved when each member of the team has the necessary SA to perform their role required for his or her mission area responsibilities. Each team member must have SA on elements relevant to their personal role. Shared SA is the mutually relevant SA needed to achieve the mission or purpose of the team as a whole. Shared SA is that required among every team member needed to create a successful outcome. Not all Team SA must be shared but Shared SA must be adequate to accomplish the mission.

High performing teams depend upon a high level of SA among individual team members for the aspects necessary to perform their job while an accurate, common operational picture is developed by sharing those aspects of the situation common to the needs of each team member (Endsley & Jones, 1997, 2001). Effective CRM can be seen as the framework on which a high level of SA can be developed.

Four factors are used to describe how teams build and share SA (Endsley & Jones, 1997, 2001). The factors are requirements, devices, mechanisms and processes. Team SA Requirements are the degree to which the team members know which information needs to be shared, including their higher level assessments and projections which are other team members are not aware of, and information on each team members' task status and current capabilities. Team SA Devices are available for sharing this information, which can include direct communication in verbal and nonverbal form, shared audio and visual flight displays, or a shared environment.

According to Endsley and Jones (2001), Team SA Mechanisms are the degree to which team members possess mechanisms described as shared mental models or ways of thinking, which support their ability to interpret information similarly and make accurate projections regarding each other's actions. The possession of shared mental models eases and facilitates the need for carefully choreographed communication. Team members share a common operational picture limiting the need for description and development. Trends are seen to unfold in a mutually understood, predictive fashion. Team SA Processes are the degree to which team members align effective processes for sharing SA information which may include the team process of questioning individual and common assumptions, advocacy of positions, checking each other for conflicting information or perceptions, setting up coordination and prioritization of tasks, and establishing contingency planning (Endsley & Jones, 1997, 2001).

Two categories of criticism are found in the literature. The first is a criticism of measurements as to accuracy and relevancy of what is being measure. Given experience, effects of time on memory and intelligence and the rapid cognitive process that SA entails accuracy is a debatable point and that implicit measures may be more realistic (Durso, Rawson, & Girotto, 2007). The second category of criticisms concerns the validity of SA as a construct itself. SA has been viewed as an unnecessary construct altogether given existing elements such as attention (Dekker & Hollnagel, 2004; Dekker & Woods, 2002).

Automation Surprise as a Threat to SA

Aviation automation surprise is a phenomenon that occurs when pilots employing technological systems employed during flight operations hold a mental model of the automated output that does not reflect the behavior that is actually produced by the technology (Rigner & Dekker, 2000; Sarter, Woods, & Billings, 1997; Wiener, 1988). This surprise in that the aircraft or system is not reacting according to the predicted outcome leads to increased workload, reduced efficiency, loss of SA and flight safety risk.

Digital avionics and control systems within the cockpit automate such pilot tasks as flight profile, fuel planning, system diagnostics, navigation and environmental settings for the cockpit and cabin. The automated systems are intended as devices to reduce cognitive workload, nuisance tasks, error reduction and pilot fatigue (Casner, 2008; Sarter, 1996). The literature reports that workload is not always reduced in particular high workload environments, such as takeoffs and landings. Instead, workload is increased and pilot distraction becomes a possible threat (Scerbo, 1996; Sheridan & Parasuraman, 2000). The vigilance tasks, or the monitoring of the automated systems during high workload environments become a distraction or threat as operational tasks demand an increased amount of pilot attention. Damos, John, and Lyall (2005) note that though time spent on tasks concerning the yoke and throttle may be reduced a resultant increase in crew coordination communication regarding systems occurs. If the communication is disrupted the team and shared SA is negatively impacted.

Sarter and Woods (1991) note cockpit task management is altered with automation when systems operate as expected but the surprise occurs when the flight and control systems react in a way that the surprises the understanding of the pilots. The surprise can result in what the literature describes as human-machine conflict. In 1994, a common example across the literature of human-machine conflict occurred in Nagoya Japan (Billings, 1997; Sarter, 1996; Sarter et al., 1997). This conflict needs to be thought of as the opposite of human-machine interface, or harmonious implementation (Sarter, 1996). Billings (1997) describes the need to think of the aircraft as a child-like active participant in the system, innocently attempting to do what it was told to do. In the Nagoya case the automation ran counter to pilot intent resulting in the loss of lives and aircraft.

Sekigawa and Mecham (1996) describe an aircraft crash of an Airbus 300-600 on approach to landing in Nagoya Japan on April 24th of that year. During the approach the copilot inadvertently activated the automatic systems that cause the aircraft to automatically go to increased thrust, assume a climbing attitude, climbing away from the runway in a "go-around" mode (Sarter et al., 1997). This mode of flight is completely automated with all flight controls and aircraft thrust driven by redundant computer systems. When the pilots saw the aircraft moving in this unintended direction, and not knowing why, they increased downward control stick forces in an attempt to manually fly back towards the runway. The computers sensed this as contrary to the "go around" profile and increased the automatic nose up inputs, including trim. In effect the pilots and automated systems were wrestling for control. The full nose up trim that resulted caused a violent nose up pitch when the pilots assumed manual control and resultant near vertical stall. The crash claimed 264 lives.

The Nagoya case is described in control theory as the classic case of aviation automation surprise (Sarter et al., 1997). The failure of human operators to anticipate the machine's response to their activities resulted in confusion, loss of CRM and SA. The human-machine system had entered the unknown unknowns regime according to Sheridan and Parasuraman (2000). The pilots were unsure of what they did not know and also the reason for the machine's reaction.

The root cause for automation surprise is a cognitive mismatch between the mental models of the pilots and the behavior of technology (Parasuraman, Mouloua, & Malloy, 1996). The disparity between understanding what should happen and what is happening from the pilots' perspectives can be reduced with experience and training (Sarter & Woods, 1991; Wiener, 1988). Pilots need significant operational experience of a year or more, roughly 1,200 hours of flight operation, to fully understand the automated systems involved and prevent the automation bias that occurs when the humans in the sociotechnical system trust the technology excessively (Dixon & Wickens, 2006). Bias results when the technology acts as a replacement for the vigilant information seeking, processing and sharing that should occur in well functioning CRM applications. Training in use, along with awareness of threats, error and risks resulting from automation bias in mode and mode awareness of the systems will result in understanding of inputs, processes and outcomes for tasks and automation (Bjorklund, Alfredson, & Dekker, 2006).

Adult Education

Andragogy as developed by Knowles and explained in Knowles, Holton, and Swanson (2005), Kolb's (1984) Experiential Learning and Revan's (1982) Action Learning were chosen as foundational literature for review based on work for the unique environment of aviation education by Bye and Henley (2003), Conrad and Harris (2003), Henley (2003), as well as Turney (2003). In adult education, the professor or instructor becomes a facilitator, consultant and change agent. He or she is responsible for preparing, in advance, the learner for understanding roles and technology in this new setting. The professor or instructor designs a climate in the class, simulator or aircraft conducive to learning that must remove barriers such as fear of failure or friction caused by new technology. To the extent possible learning should be problem based and approached in a team format emphasizing collaboration and learning. Technology should be part of the learning and not in addition to the learning outcomes. Andragogy, Experiential Learning and Action Learning literature support the applicability of those frames in these learning environments (Bye & Henley, 2003).

Andragogy

The teacher becomes a coordinator of mutual planning (Brookfield, 1986; Knowles et al., 2005). Traditionally teachers or instructors have been concerned with an intended outcome in classrooms and as part of flight instruction. In the case of andragogy it is possible each student would plan on a different outcome from the same classroom engagement dependent upon his or her own needs given professional experience or previous education. The needs of an adult learner are emergent and arise organically as students bring in specific life experiences (Brookfield, 1986; Mezirow, 1990). This leads to continuous diagnosis of the learner, material and class structure on an individual basis by formulating content matched to those needs. This content exists inside a pattern of learning experiences that intersect with classmates and other people encountered in life, as well as the instructor.

The instructor is responsible for determining the choice of materials the students would be exposed to but realize that the choice may shift as learning progresses and student needs dictate (Bye & Henley, 2003; Knowles, 1990; Mezirow, 1990). This enhances the role of technology to acquire information since the choice of a single text or source probably will not satisfy the emergent, organic needs of the student (Conrad & Harris, 2003). The learning is seen as a closed loop system with feedback coming from life, other students and teachers. As the feedback is considered, modifications to the inputs and learning processes would be adjusted to meet the evaluation of learning progress (Knowles, 1990).

Andragogy is, by design, an individual transactional model for adult learning (Knowles, 1990). In practice, this requires that there is consideration for the learner's need to know things important to their lives that probably had not been captured by curriculum in the past. The learner needs to know why, what and how the material they are learning will apply immediately to the betterment of their jobs or orientation. The learner is seen as autonomous and self-directing in school, just as they are in life. If the learner has not achieved the ability to self-direct, they would not be candidates for adult learning in any sense, which is dependent upon internal motivation. Given high demands in effort, time and sacrifice, aviation education and training has the same need for internal motivation (Bye & Henley, 2003). This is not to say that students would not be responsive to different training methods or direction, or even a more formal class approach, but that andragogy would not work without the intrinsic motivation of the student.

Andragogy emphasizes that the learner's past experiences are the foundation upon which to build and a resource to be used (Knowles et al., 2005; Marsick & Watkins, 1990). The use of these experiences creates a readiness to learn when new material is related to work and life as the subject matter supports developmental activities (Henley, 2003). The adult learner is problem centered in outlook, problems exist at work and to prove useful adult learning must aid in addressing those problems. The learning is in context, rather than abstract and the motivation intrinsic as the learner seeks a personal satisfaction through accomplishment and recognition.

Traditional adult training and education, even in the best of cases, often still centers upon a teacher talking about material prepared by academics that often has little to do with practical application for those organic learner needs (Knowles et al., 2005). The learner is told requirements, intended outcomes, what resources are required, as well as how and when to use them. Case studies are about other organizations, absent relevance to real work, and collaboration between the student, teacher and work was often not centered on real life problem resolution. This imposed structure impinges upon the adult's developed psychological needs to self-direct and take responsibility for desired outcomes (Knowles et al., 2005).

Experiential Learning

Exploring Kolb's (1984) Experiential Learning is a requirement for understanding educational effectiveness for adults while engaged in dynamic, social situations. Social learning is continuous and ongoing; knowledge is created, reflected upon and integrated into future activity with other people in a practice (Brookfield, 1986; Kolb, 1984; Knowles, 1990). Social experiential learning involves reflecting upon one's experiences within the contextual frame of activity one is engaged in and assessing the results or outcomes from that activity to lead into refinement of further actions. This is an action theory seeking to answer the question of what actions achieve the desired consequence in a given situation as articulated by Lewin (as cited in Knowles et al., 2005). Kolb and Knowles (1990) recognize knowledge created through the transformation of action to experience. This creates learning while doing and is based on knowledge inseparable from experience and context. Kolb notes this relationship between education and experience, with knowledge as the construction of experience.

Kolb's (1984) experiential theory is composed of four continuous steps in a cyclical flow. The cycle begins with concrete experience, or as proposed in Knowles' (1990) andragogy, what does the learner bring? This is followed by reflective observation considering how the situation or activity will unfold if actions are taken or a plan is placed into effect based upon the learner's desired outcomes. A plan of action or conceptualization is developed followed by active experimentation or participation with the flow yielding a concrete experience.

Action Learning

The first documented reference to action learning was recorded by Reginald W. Revans in 1945 (Revans, 1982). Revans encouraged the field managers of a British coal mine to learn from each other in a team-based environment so as to find solutions to the problems workers faced in the mines (Revans, 1982). Revans believed that effective learning occurred when asking questions about real life work problems that did not have an apparent answer. He created his theory to highlight that learning is generated within an organization when individuals are presented with opportunities to use programmed knowledge conveyed in structured learning environments, coupled with questions in the team frame focused on real-world problems and with time for active reflection as to results (Marquardt, 2004; Marquardt, Leonard, Freedman, & Hill, 2009; Raelin, 2000; Revans, 1982).

Action learning teams, referred to as a "set" in Revans' work, were individuals who volunteer to participate in the group and represent a cross section of the organization. The team was given the authority to solve organizational problems and is to challenge common assumptions by asking questions about the larger system as well as the problem itself. The charter intended the team to learn while doing. During the formation of action learning groups, individuals should embrace a learning environment and set aside preconceived ideas about solutions. The intent was that the individuals in the group learn from each other through self-reflection and evaluation. Some literature recommended use of a facilitator, sometimes called a set advisor, to assist the group in asking questions aligned with organizational mission but with application to the problem at hand, probing further systemic issues, providing a balance for the interaction and challenging assumptions, although use of a facilitator was not advocated by Revans (Marquardt, 2004; Marquardt et al., 2009; Pedler, 1996).

A self-facilitated group can be highly successful when the members are committed to adhering to agreed upon team rules, focusing upon critical reflection, asking questions of the problem as well as mental models, personally owning the problem situation and willing to provide time for self reflection (Marquardt et al., 2009).

Action learning literature emphasized the value of asking the right questions rather than seeking the right answer, using the Socratic method to inspire deep critical thinking about the problem (Revans, 1982). Critical self-reflection in action learning uses lenses of self, others, history and expert opinion to develop full understanding (Brookfield, 1986). Action learning helps unlock the potential of people by empowering individuals to ask questions and explore alternatives to problems when there is no known solution (Marquardt, 2004; Raelin, 2000). Each individual is challenged to own the problem situation, while the team is there to provide support, encouragement and probing inquiry.

Revans (1982) included three areas of action learning in his discussion on the action learning cycle. The first areas is the rational decision cycle using survey, first decision, pilot run, evaluation and final decision. The second learning sequence was awareness of ignorance, creation of a new idea, taking an experimental chance, watching effect, and learning for next time. The third cycle was advisory argument, either given or received beginning with an admission of need, choice of counsel, test of confidence by action, estimate of outcome finished with acceptance or rejection as to applicability of results. Additionally, Revans recognized there are five components in the scientific method: (a) observation, (b) hypothesis, (c) trial, (d) audit, and (e) review. In the action learning cycle, three of the five components are the same: (a) deciding, (b) learning, and (c) advising. Revans theorized the two processes, the scientific method and action learning, both recognized real people work in real systems, and within these two systems that there can be no action without learning, and no learning without action.

Marquardt (2004) titled the action learning cycle the action-learning framework based on the work of Smith in 2001. Like Revans (1982), Marquardt's framework also focused on three key areas of (a) focus, (b) will and (c) capability. The focus area builds knowledge, gathers facts and aims to answer the question of topic or subject. During the will stage, participants move toward their feelings, emotions, and the personal commitment ending with the capability stage. In the capability stage the skills of the participants, along with the budget or resources needed are determined. In the capability stage, the group must determine the methods and processes to move toward action (Marquardt, 2004).

Pedler (1996) explained and illustrated a simple circular flow of an action learning cycle beginning with an action on the problem followed by learning from the actions through the third step of reflective questioning before concluding with a new identified problem of idea leading back to the original starting point of action on the identified problem. Pedler noted action learning's major contribution is the creation of an organizational culture of inquiry, which is an essential aspect of the learning organization. The ideas developing from these action-learning cycles benefit both the individual and the organization as the experience and items learned guide managerial decision making grounded upon the results of employee work aligning strategic purpose with organizational tasks.

The great attraction of action learning is its unique power to simultaneously solve difficult challenges while developing people and organizations at minimal cost

(Marquardt, 2004; Marsick & Watkins, 1990; Raelin, 2000). Action Learning inspires innovation to creatively act and learn at the same time. Innovation has become essential in a workplace that is rapidly changing and that faces evermore unpredictable global challenges, which is why companies and organizations such as General Electric, Motorola, Southwest Airlines and the United States Army apply the principles (Marquardt, 2004). The intent of action learning is that each individual within the group is changed because of the power of self-reflection and engagement with problems aligned to organizational objectives. These individuals return to the regular work environment, altering their interactions and behaviors. Others observe these changes and begin to model those actions. With Action Learning a learning organization can be developed, where new knowledge evolves into different behavior that is replicable creating innovation, knowledge sharing, organizational change and leader development (Marquardt et al., 2009).

The literature reinforced that for action learning to be successful, it is imperative that the leadership of the organization exhibit integrity and authenticity with its own behavior (Revans, 1982). The organization must also have a high level of trust among individuals, a core fundamental value system and a willingness to be creative in their approach to solving problems. Well-intentioned mistakes must be acknowledged as unavoidable and part of the learning process. These factors are the foundational organizational characteristics that are ideally suited for action learning to be successful. Action learning requires that there be collaboration across organizational levels to produce a lasting effect (Marsick & Watkins, 1990; Raelin, 2000).

Action learning is not a strategy that is clearly defined (Marquardt, 2004; Marquardt et al., 2009). Marsick and Watkins (1990) explained the father of action learning, Revans, did not want to clearly define action learning but only explain contrasting theories to allow flexibility and not decrease action learning's organizational possibilities. The practical focus on work structure and application of action learning on the job allows easy integration with other techniques or strategies. O'Neil and Marsick (2007) note Action Learning is unique in the way it influences people from many directions and on multiple levels providing a framework in which transformation is possible. This lack of a clear definition, however, has led to differing views of action learning, including the development of four different action-learning schools.

Within the action-learning arena, four different schools have evolved containing the action learning practices supporting the different types or ideas of action learning. These frameworks of action learning practices based on organization, anticipated outcomes, and differences in how learning occurs evolved. Based on O'Neil and Marsick (2007), the four schools include the (a) tactical school, (b) scientific school, (c) experiential school and (d) critical reflection school.

In the tactical school, learning is incidental and not the highest of priorities. Action and results are critical outputs for the tactical school. The scientific school is based on the scientific method. Using a scientific approach, a formula was created by Revans with L=P+Q where L is the resultant learning, P is the programmed instruction and Q is the questioning insight (O'Neil & Marsick, 2007). A large piece of the scientific school is the questioning and problem-solving aspects (Marsick & Watkins, 1990). In the experiential school, the core foundation builds from Kolb's (1984) learning cycle using resident experience, followed by reflecting upon the experience to conceptualize new ways of doing something, experimenting with different ways to achieve the goal and starting over with a new cycle as one learns from the experience.

The critical reflection school differs from the experiential school because it includes the explicit intention of developing reasons for critical reflection (O'Neil & Marsick, 2007). The critical school is intended to taking reflection to the level of mental assumptions and biases, thinking not only of problem solution but how original thinking led to the problem. Each school's philosophy builds upon the foundation of action learning but the schools are differentiated by the desired outcome or goals for the separate designs.

Kirkpatrick's Four Levels of Training Effectiveness

Kirkpatrick (1959, 1996) proposed four levels of evaluation as to training results and effectiveness. The first level is a measure of the student's reaction to the training and is captured as the training is completed. The measure is generally done with a survey capturing the student's observations as to the quality of the instruction, the material presented and the physical surrounding's contribution to a positive learning experience (Kirkpatrick & Kirkpatrick, 2006). Abernathy (1999) notes Level One was described as an initial response and may be subject to both relational and preconceived biases that cause poor responses, which may then result in over reaction by the trainer's or organization sponsoring the training.

Kirkpatrick's (1959, 1996) second level of training effectiveness assesses the student's ability to demonstrate subject mastery of the learning objectives within the specific training environment. The second level is referred to as learning and is described as an increase in knowledge or skills measured with a pretraining assessment on subject matter and an end-of-training assessment. The second level of training effectiveness is a measure of knowledge gained. Davis, Davis, and Van Wert (1998) noted that less than a third of material retained in the training will actually result into enhanced employee skills within the actual job environment. Galloway (2005) noted that the assessment relies heavily upon the relationship between trainer effectiveness and data provided by the participants themselves, which may be removed from the job and not aligned with organizational purpose. This split between the training intent and organizational purpose while useful to the training itself, does not necessarily provide organizational value.

Level Three sought to measure posttraining behavioral change as to training participant's level of skills and aptitude for the job the training was intended to support. The intent is to acquire Level Three data some period of time, usually several months, after the training event. Phillips (1994) emphasized the need to measure this level relative to contribution to success in achieving organizational goals as well as the recognition that the training and development process it may have strengths or weaknesses that contributed tot the behavioral change. Level Three allows an additional opportunity to retrieve feedback from the training participants as to applicability to the real-world task at hand. Phillips questioned whether supervisors on the job site have the time and requisite understanding to assess the effectiveness of the training as seen in behavioral change. Meanwhile, those conducting the training may not be proficient in the job itself yielding imprecise understanding of behavioral adaptation.

Level Four sought a measure of results as to the as seen from the view of the organization itself. Evidence is sought to verify that the training has contributed to the purpose of the organization measured by a success measure such as improved quality, enhanced customer satisfaction, reduced cost, better mission readiness or higher material conditions. This level measured effectiveness of training as aligned with organizational strategic intent and purpose (Kirkpatrick, 2004; Kirkpatrick & Kirkpatrick, 2006; Phillips, 1994).

Despite historic evidence of effectiveness, accepted application within organizations across sectors and logical development with additional research Kirkpatrick's efforts have been criticized for being simplistic and absent tie to final business measures such as Return on Investment (RoI; Galloway, 2005; Phillips, 1994). Davis et al. (1989) emphasized the requirement for RoI analysis to address executive need for connection between training investments and business results.

Phillips (1994) added a fifth level to Kirkpatrick's (1959) four with an investigation of RoI. The training was evaluated specifically within the frame as contribution to return within a strategic function. All costs of training are realized specific to a strategic outcome. Improvements to that strategic function are measured year over year and the cost and effectiveness of training can then be presented with a percentage increase or decrease in performance. Kirkpatrick and Kirkpatrick (2006) question the feasibility and accuracy for this method within organizations since there must be a very specific tie between training and strategy as will as a way to assess numerically the results. In some situations, such as a nonprofit or educational institution results may not be either numeric or dollar based. Phillips does find the RoI method useful as the intent of tying training to the organization's strategic purpose creates value in and of itself.

Summary

Schumpeter's (1975) creative destruction presents a compelling case for the unintended outcomes development of technology may have on society and organizations as parallel technology emerges from outside market considerations creating destruction of existing structure and work processes. Disruptive innovation details how this technology may enter from a point of unintended competition as new uses are found for devices that then prove more useful and less expensive than existing alternatives. The technology then grows to supplant established competition from a lower to upper end of the spectrum.

The acceptance of technology is not a given since individuals will create attitudes towards the use of technology based on perceived ease of use and usability, as well as their own self-efficacy as to the technology. User acceptance is also influences by social considerations from respected colleagues and the level of support the organization provides.

Research into CRM provides compelling evidence that the better crew coordination brought on by sound application of CRM has contributed to safer flight operations. The use of CRM enhances the development of a crew's SA possibly improving the quality of decisions made. Technology has a role in both CRM and development of Team SA as devices aid or hinder the sharing of information. Understanding the effectiveness of adult education and training is needed to realize acceptance of the technology in use. Aviation education and training brings together a variety of experiences and understandings as to the relevancy and usefulness of technology in flight operations.

Chapter 3: Methodology

Airline flight safety continues to advance, improving opportunities for travelers and commerce to safely transport passengers and goods around the globe. One of the contributors to increased safe flight is the improved crew coordination and management of the cockpit technology brought about with the implementation of CRM. The purpose of this exploratory study was to develop understanding of the capabilities and risks concerning the implementation of tablet computers into flight operations for airlines as a replacement for paper manuals and navigation charts. In addition the study explored possible impacts to CRM and SA with extended implications to flight safety or enhanced performance.

Restatement of Research Questions

The general research question that this study attempted to answer is "What opportunities and risks lay in the implementation of tablet computers for airline operations?" Specific research questions guided the design of the study:

1. What will be the impact of iPads on the efficiency of flight operations?
2. What will be the impact of iPads on CRM?
3. What will be the impact of iPads on SA?
4. What expanded capabilities might tablet computers bring to flight operations?

Research Design

Babbie (1989) and Stebbins (2001) note that an exploratory design using qualitative data methods is appropriate when problems are in a preliminary stage of development. Because of both the uniqueness of the problem and the rapid change in accompanying technology, systematic research is difficult to execute and subject to shifting frameworks given the emergent nature of problem development. Creswell (1998) and de Vaus (2001) advise the use of qualitative research when a topic needs further research, lacking identifiable variables or established theories to explain possible cause and effect frameworks within a specific population. In the case of iPads or other tablet computers, the implementation authorization occurred in March of 2011 (FAA, 2011) and the actual introduction of the technology began in Fall of 2011 at major U.S. airlines as shown with literature reviews and background information.

Babbie (1989) proposes that the qualitative research be supplemented with mixed-methods such as an initial quantitative survey, to facilitate subsequent questions and strategies for data collection. Bryman and Bell (2007) highlight that an initial survey or questionnaire facilitates subsequent interviews by aiding in the selection of interview candidates, acquiring information to develop semistructured interview questions and to add contextual information that cannot be obtained by other means.

The Need

No models, practices or roles have been designed for the training, implementation of technology such as the iPad into a commercial cockpit or the influences upon CRM or SA (M. Yeh & D. C. Chandra, personal communication, September 14, 2012). Babbie (1989), de Vaus (2001), and Stebbins (2001) recommend an exploratory research design when researchers have little or no knowledge about a group, activity, process, system or situation but have reason to believe that elements worth discovering will be revealed as a result of the research. In these cases the goal of the exploration was to create new ideas, knowledge and perspectives looking for common themes emerging from the data collected. Given a better understanding of parameters and variables subsequent qualitative research can be used for follow-up research. Qualitative methods are best used in the initial exploratory study while quantitative surveys may be used with the subsequent research (de Vaus, 2001; Stebbins, 2001).

This research attempted to capture and explore the opinions of knowledgeable practitioners concerning the role of tablet computing in the modern airliner cockpit. Using both de Vaus's (2001) and Stebbins' (2001) work, the effort is categorized as social research as aspects of meaning and relevance of actions, concern for issues, how people relate and understanding of actions are sought to be understood. The goal was to determine the influence of tablet computing in the conduct of safe airline operations.

Data Sources

For this study, data sources were professional pilots holding an Air Transport Professional rating and employed at a major U.S. airline as outlined in the operational definitions from Chapter 1. Using the approach of surveys to develop initial understanding, surveys sought those with experience using iPads in the cockpit so as to then identify sources of interview data as well as enhancing the validity of the interview questions asked.

This effort was an exploratory study using the survey in Appendix A to develop understanding of practitioner insight followed by interviews concerning the phenomena of iPads within the cockpit of a commercial airliner. As described by de Vaus (2001), the exploratory design benefits from multiple methods of data collection given the rapidly changing nature of the phenomena. Because de Vaus notes that exploratory studies are used to investigate real life situations with empirical inquiry into contemporary phenomena that operate within close relationship of context and the phenomena, the use of a exploratory study paradigm for iPad application in flight fit within this criterion well. The first phase involved a survey of airline pilots that are familiar with iPads in commercial flight operations. The intent was to capture keys for success specific to implementation and use of the technology. The second phase involved interviews with voluntary participants using questions derived from the surveys and literature. The intent was to achieve understanding as to application of lessons of iPad use to understand risks as well as opportunities for improving operations.

Sampling Procedures

Participants for this study were identified through the Airline Pilots' Association (ALPA) websites and forums via a request for participation in a survey asking about experiences in the training and use of iPads. Brynam and Bell (2007) and Creswell (1998) note that for emerging phenomena research can begin with surveys to help understand themes that are relevant to practitioners. The themes can then be used to develop a semistructured interview. The survey was distributed through Zoomerang. A final question in the survey asked if the respondent wished to participate in a semistructured interview. Based upon the responses, 12 candidates for semistructured interviews were selected using random number generation with one random meeting that led to an interview with the pilot in charge of government coordination.

Phone and email contact with the leaders of ALPA from airlines that have implemented iPads in the cockpit, along with the Director of Technology at a major airline, the program manager at Jeppesen and Apple Computer were also made to gain additional background information. An onsite visit to the airline's training facilities was accomplished.

Babbie (1989), Creswell (1998), and Stebbins (2001) advise the optimum size for qualitative research interviews is fewer than 20, but more than 10. Thirteen pilots were interviewed as part of the study. The effort relied heavily on interviews and a sample of this size allowed the researcher to become immersed in the field and establish a professional relationship with the knowledgeable respondents.

Data Collection Strategies

The primary instrument of data collection for this study was a Likert-scale survey of questions to develop themes for semistructured interviews, followed by open ended 40-minute interviews, either in person or by telephone, with the participants. In comparing the advantages of interviews to personal observations for qualitative research, Bryman and Bell (2007) note that interviews allow the researcher to find out about issues that are not easily observed and provide access to a broader range of people and situations. Factors such as scheduling, richness of conversation and concern for privacy make the long interview valuable for qualitative study (Babbie, 1989; Stebbins, 2001). Because the members of ALPA are geographically dispersed, logistics necessitated interviews over experimental observation for this study. Also, the study sought to elicit the subjects' expert opinions by phone when in person interviews are not logistically possible.

For exploratory studies in particular, interviews are more focused than observations because the researcher typically uses an interview guide with questions drafted from prior observation and the literature review (Stebbins, 2001). Three degrees of structure can be found in interview formats: (a) structured, (b) semistructured, and (c) unstructured (Bryman & Bell, 2007). The choice of approach depends on the goals of the study and expertise of the interviewers and the interaction with the interviewees. Given the emergent nature of an exploratory study the semistructured interviews allowed the framework of training, CRM and SA, coupled with acceptance of technology, to come together for consideration of the impact upon flight operations.

de Vaus (2001) and Stebbins (2001) suggest that open-ended questions are well suited for exploratory studies because they allow for open mindedness and flexibility while allowing for clearly defined topics. They compare the process of exploratory research to setting up a meeting agenda. In order to prepare and then achieve meeting objectives a plan is set based on projected research needs and goals but time is allotted for other opportunities so as to gather information as needed.

In this study, both the researcher and interviewees were professionally trained airline pilots familiar with and well versed in the subject matter of airline piloting and the implementation of the iPad into flight operations. Therefore, open-ended interviews ranging up to 60 minutes in length were appropriate as the most effective and efficient data collection method for this study.

Data Collection Process

The collection process involved an initial web-based survey using professional pilot forums to solicit volunteers. As part of the survey volunteers were sought for follow on interviews. To mitigate bias, random selection of subsequent participants was used. Random selection ensured each volunteer had an equal chance of selection

The email recruitment letter for potential participants who were randomly selected for the follow on interviews is attached as Appendix B. Those who agreed to the study were provided with the informed consent (Appendix C). Participants who were geographically distant from the researcher were sent the informed consent through email and asked to sign, scan and return to the researcher through email.

After the informed consent was received, a request was made for a 60-minute one-on-one interview. The interview was conducted either by telephone or in person, depending on the availability and location of the subject and researcher. Telephone interviews were conducted and recorded through a laptop voice over Internet recording device.

Participants were not given questions in advance in order to maximize spontaneity in the interview. An interview protocol with five open-ended questions (see Appendix D) was used to guide the conversation. The questions in Appendix D are provided as examples, having been refined upon study of the survey results in order to develop themes. Bearing in mind that the best interviewer is also a good listener, the researcher was at all times respectful, courteous and refrained from offering advice (Creswell, 1998). The interviews were recorded with a digital audio recording device and the researcher took backup field notes. All interviews were transcribed and submitted back to each participant to ensure the accuracy of the data. For privacy protection, the interview data has been kept on a password-protected laptop stored in a locked cabinet belonging to the researcher and the field notes are kept in the same cabinet.

Data Collection Tools

Qualitative interview schedules may involve specific questions or areas of questioning conversation. de Vaus (2001) emphasizes that researchers must carefully think through what information is required to answer the research questions. Areas of questions must be general enough to capture flexibility in response given the emergent nature of technology as new capabilities are uncovered. Based on the literature review and research questions refined after the survey five themes emerge for the interview schedule. These questions will be modified or replaced dependent upon themes emerging from the survey results. The initial topics to be reworked following analysis of the survey results were:

- The role of acceptance of tablet computing technology in the cockpit given proper training, education, usefulness and usability.
- The opportunities the tablet computers offer to enhance CRM through better information sharing inside and outside the cockpit.
- The contributions the connectivity power of tablet computers offers for enhanced SA for the flight crews.
- The disruptive potential tablet computers offer to either improve flight safety performance or create risks with unintended outcomes.
- Increases to the scope of use to integrate tablet-computing capabilities into the aircraft monitoring system.

These topic areas acted as Stebbins' broad guidelines to frame the exploratory research. An interview protocol was drafted and attached as Appendix C containing open-ended questions that guided the interview with the themes listed above. Academic colleagues from university education faculties reviewed the interview themes and guide for face validity and academic rigor. The reworked questions are provided in Chapter 4.

Validity and Reliability of Instrumentation

The survey instrument was crafted using the UTAUT from Venkatesh et al. (2003) as a base to modify to specific questions related to aviation operations with technology. As described in Chapter 2, the UTAUT is an instrument specifically designed for valid applications to a variety of technologies and consistently returns a validity of greater than 70% in those applications.

Meta analysis from King and He (2006) indicate the key constructs of the UTAUT model have an average reliability as measured by Cronbach's alpha of .87 with a variance of .007. The range for the reliability is between .63 and .98 for each measure. The analysis covered 57 studies between 2002 and 2005 using the model to access the Perceived Ease of Use, Perceived Usefulness, Behavioral Intention and Attitude Towards Using. The Cronbach alpha results indicate a high level of reliability with this instrument.

de Vaus (2001) emphasizes that researchers must be confident that the research design can sustain the conclusions that are drawn from the data. Internal validity is the extent that the structure of the research allows unambiguous conclusions can be drawn from the results. The way the research is set up can eliminate alternative solutions. The researcher is responsible for the validity in the data collection. de Vaus recommends that qualitative researchers employ specific processes to ensure internal validity and verification that the results avoid ambiguous outcomes. Researchers in qualitative research should be consistently engaged in the field of study and carry appropriate levels of knowledge to understand the context of the responses. The researcher for this dissertation ensured the results of qualitative research were taken back to informants to act as member checking and ensure the accuracy and credibility of the interpretations. Academic colleagues will be debriefed periodically as to the results, as part of peer review. Bias, such as previous experiences as a pilot or educator should be revealed so as to create transparency. Finally descriptions of the findings will be detailed to determine transferability to other research (Creswell, 1998; de Vaus, 2001). As an additional measure for validity, data sources should be given transcripts of their interview for user validation.

Using returns from the survey questions seeking volunteers for interviews, the candidates were subjected to random sampling. Random sampling methods as described by Bryman and Bell (2007) will ensure adequate representation in the sample of the population study for the interviews. Bryman and Bell emphasize that choosing a representative sample as done with random methods helps ensure external validity, which addresses whether the results can be generalized beyond the original research context. The sample will be representative because a very small population of pilots will be contacted until the theoretical saturation of sufficient interview numbers for qualitative research are reached (Creswell, 1998). There will not be "representativeness" as delineated by a probability sampling strategy.

Reliability is seen as the repeatability of the study. By writing a detailed description of the study process greater reliability can be achieved (Bryman & Bell, 2007). Stebbins (2001) emphasizes that judgments about reliability and validity of a study can only may when the research is collated and compared with other research on the same topic. This research into tablet computers in airliner cockpits was intended to be the first in a series of other studies on the same topic. Quantitative survey methods would seem useful in following research to evaluate the acceptance of technology in the cockpit and training effectiveness. Recommendations for future study have been made for further research based upon available instruments such as the TAM and Kirkpatrick's Levels of Training Effectiveness.

Data Analysis and Interpretation

Stebbins (2001) describes exploratory researchers as inductive theorists. The principle mission of inductive theorists is to create descriptive and generic concepts along with generalizations of topics that do not have a clearly defined history of research. Researchers make a concerted and systematic effort through direct, empirical observation of a group, process or activity. To create meaning from the observations researchers must carefully transcribe recordings and notes in order to create summaries, receive feedback from participants and then create visual and tabular displays to depict categories of information developed from collected data.

Data analysis consists of examining, categorizing, tabulating, or otherwise recombining the evidence to address the initial propositions of a study. Yin (1994) notes the analysis of qualitative data is one of the least developed aspects of exploratory methodology. The researcher needs to rely on experience and the literature to present the evidence in various ways, using various interpretations. Creswell (1998) suggests that categories of information or themes should be created to categorize observations and data under the title of labels. Exploratory data should be developed in spirals with the first loop of the spiral concerned with the management of analysis and organization of data. The second outward loop of the spiral classifies and interprets the data developing recurring themes from which understanding of the explored activity might be developed. The intent of the categorization is to reveal patterns from the research that allows the formation of hypotheses and theories giving indication further research will be of use.

This categorization of data becomes necessary because statistical analysis is not necessarily possible. Miles and Huberman (1984) have suggested alternative analytic techniques of analysis in such exploratory situations, such as using diagrams to display the data, creating displays, counting frequency of events, ordering the information based upon occurrence or priority assignment to terms. This prioritization must be done in a way that will not bias the results.

Yin (1994) and Trochim (1989) provide analytic techniques to fit within a larger analytic strategy. The strategy guides decisions as to what data will be analyzed for what reason to create information for the researcher. Some possible analytic techniques are pattern-matching, explanation-building and time-series analysis. The analysis itself should be founded upon the theoretical propositions found in the literature review as part of the exploratory research. If the theoretical propositions are not found in literature the researcher should consider developing a descriptive frame of reference around which the exploration can be organized

Trochim (1989) offered that pattern matching is one of the most useful strategies for analysis for exploratory research. This technique compares a scientifically developed pattern with a predicted one. If patterns match, the internal reliability of the study is solidified. The relationship of the predicted and actual pattern might not have any quantitative criteria, being instead based on common attributes. The experience of the researcher and colleagues is therefore required for interpretations, but bias should be mitigated with additional peer review.

Explanation building is considered a form of pattern matching and is useful in exploratory research (Trochim, 1989). The data analysis is carried out by an explanation of the observed activities or responses. This implies that explanation building is most useful in explanatory research, but it is possible to use it for exploratory research as well as part of hypothesis creation (Trochim, 1989). The process of explanation building follows an experiential learning cycle as a theoretical statement is offered, data and observation refines that statement, the proposition is revised as to content and meaning and then a refined hypothesis is tested once again. Trochim (1989) warns that a loss of focus is a possibility in this iterative cycle.

Time-series analysis is a well-known technique in experimental and quasiexperimental analysis. Given the reliance upon dependent and independent variables and reliance upon regression techniques the application is best suited to quantitative data and has limited applicability to exploratory research (Trochim, 1989)

A researcher must be knowledgeable of the topic being explored according to Yin (1994). The researcher must be aware of, and explicitly depict that, the analysis is of high quality, all relevant evidence was collected, competing outcomes considered, significant aspects have been considered and the specific research results address the questions asked.

Achievement of Research Purpose

de Vaus (2001) and Stebbins (2001) stated exploratory researchers must be careful about the extent to which their study can be generalized to larger topics and the conclusiveness of results. The purpose of this research was achieved with the development of a general understanding, presented in narrative form, of how professional pilots as aviation professionals view the contribution of tablet computing technology to CRM and SA and the dependence upon training, as well as additional growth potential in flight effectiveness given knowledge sharing. Additionally, the data collected was used to answer the research question relating to training effectiveness. A systematic portrayal of professionals' perspectives as to the role of tablet computing in a flight environment created opportunities to improve safety effectiveness and operational performance for the airline industry. Future research may include a quantitative study of pilot acceptance of the technology or training effectiveness as to return on investment for airline corporations.

Institutional Review Board and Human Subject Considerations

This study was conducted in accordance with ethical, federal, and professional standards set forth by United States regulations and Pepperdine University to protect human subjects. Approval for this study was received from the university's Institutional Review Board, which is responsible for reviewing research applications from the Graduate School of Education and Psychology. The Institutional Review Board approval letter is included (see Appendix D); along with the researcher's certificate of completion of the National Institutes of Health web-based training course "Protecting Human Research Participants" (Appendix D).

Under Pepperdine's Institutional Review Board applicability policies, this research activity was exempted from federal regulation because no more than minimal risk to human subjects was projected. However, participants may have viewed this study as posing some possible risks to their reputation, employment, or funding efforts. The researcher took steps to minimize those risks by protecting confidentiality through the coding of participant names and organizations separately and keeping the key to the code on a separate laptop and in a notebook locked in a cabinet in the researcher's home office.

Minimal risk is defined by the Health and Human Services policy for the Protection of Human Research Subjects at 45 CFR 46.102i (Pepperdine University, 2009) as, "the probability and magnitude of harm or discomfort anticipated in the research are not greater in and of themselves than those ordinarily encountered in daily life or during the performance of routine physical or psychological examinations or tests" (p. 11). In addition to presenting no more than minimal risk under federal regulations, this research proposal is projected to meet the Pepperdine University Institutional Review Board's following criteria for exemption: "Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures or observation of public behavior" (Pepperdine University, 2009, p. 16).

The researcher assured voluntary participation of the subjects by obtaining signed informed consents (Appendix C), either in person or electronically, prior to conducting the interviews. The privacy of all participants was protected, unless they elect to reveal identifying information by voluntarily signing a release included in the informed consent. The subjects were informed of their right to withdraw from the study at any time.

Summary

This chapter restated the research questions and presented the rationale behind choosing a qualitative, exploratory design for this study. The characteristics of the data sources and sampling procedures were defined, as well as methods of data collection, storage, and analysis. Chapter 4 describes the participant demographics and characteristics of professional pilots sampled for this study. Recording and transcribing processes are detailed, as well as the categorization process, coding schemes and validation. Findings for each major survey theme and research question are presented in tabular and narrative formats.

Chapter 4: Results

This exploratory study sought to describe the disruptive possibilities, as developed by Christensen and Raynor (2003), that portable tablet computing might bring to commercial airline operations. The use of the technology is dependent upon the acceptance resulting from training as developed by Venkatesh et al. (2003). Effective training results in use and integration into productivity of the organization based upon work by Kirkpatrick and Kirkpatrick (2006). In the case of iPads, productivity improvements result from improved SA as defined by Endsley (2010).

The study approached operational improvements from the perspective of users as found in commercial airline pilots. The study sought answers to questions of enhanced efficiency, productivity, management of the cockpit's resources, improved SA and potential improvements as well as capabilities that the tablets, in the form of iPads, offer. Using the exploratory methodology described in Chapter 3, the researcher conducted a survey to develop a framework of understanding of pilot acceptance of the technology, perceptions of usability and the perceived effectiveness of training. The surveys were developed using Zoomerang and the Web address was provided on union forums and at training with the use of business cards.

The surveys were returned during the introductory phase of the iPad implementation. At this point in the training, as of May 2012, 1,748 pilots had been exposed to the training and might have responded to the request for survey participation. 147 surveys were returned and in the second phase the researcher interviewed 13 pilots with the methods described in Chapter 3. The interviews were conducted from May through July of 2012, just as the iPads were being introduced into flight operations for a large, commercial airline based in the United States, but flying globally. Given proprietary and confidentiality requests from the airline, the firm will be called the "Company" going forward.

All interviews were conducted face to face either in the cockpit before flight, in airports at pilot flight operation facilities or in one case, in the airline's training department. The interview lengths ranged from 20-35 minutes and were digitally recorded. The researcher also took hand written notes. The digital recordings were then transcribed and the resulting notes reviewed over the phone with the pilots interviewed to ensure accuracy and allow corrections. The interviews, notes and review process were then analyzed for recurring themes as described in Chapter 3.

Restatement of Research Questions

The general research question that this study will attempt to answer is "What opportunities and risk lay in the implementation of tablet computers for airline operations?" Specific research questions guide the design of the study:

1. What will be the impact of iPads on the efficiency of flight operations?
2. What will be the impact of iPads on CRM?
3. What will be the impact of iPads on SA?
4. What expanded capabilities might tablet computers bring to flight operations?

Chapter 4 presents the analysis of the background of the introduction for understanding of the status, presentation and analysis from the survey results and then analysis of the emergent themes from the interviews. The background will detail specifics of the iPad implementation as found in general company documents and field observations to provide understanding and context.

Background From Company Sources

The Company originally planned introduction of 11,000 iPads into pilot operations for January 2012. Due to coordination problems with FAA officials and coordination of inspections the distribution, training and implementation were delayed until April of 2012. The Chief Information Officer for the Company was tasked with the acquisition of the iPads and implementation of training. According to an interview with a pilot assigned to the management of all pilot training, the Chief Information Officer was chosen because of budget availability, the information technology aspect of the iPad and ownership of the Company's computer resources (Senior Flight Manager, personal communication, May 14, 2012).

All 11,000 iPads were purchased as the second version or iPad 2s. The version has wireless connectivity but is not able to access the Internet through cellular technology. The iPads were loaded with proprietary documents used for flight navigation, policy manuals, technical manuals, procedures and FAA rules. The documents were loaded under a system called "Content Locker" and ran to over 3,000 pages in PDF form with 1,500 pages for navigational charts, 1,000 pages of aircraft specific technical data and 500 pages of policy documents. Due to the federal agency's concerns about iPad reliability pilots were still required to carry the large volume of actual documents weighing over 100 pounds and split into two large attaché cases. The FAA inspectors refused the Company's request to use the iPads in place of the paper documents because of concern about battery life and iPad reliability. Additionally, there was no authorized aviation-quality power adapter for the iPad in the cockpit. Given concerns about pilot distraction and storage safety, the FAA also limited use of the iPad to above 10,000 feet though the majority of the navigation and technical documents are designed for use in the landing and takeoff phases.

Plans to configure aircraft for wireless accessibility for passengers and flight crew had also been delayed due to monetary concerns with recent fuel price increases. The federal restrictions and the Company's delay in wireless introduction have limited the iPad to content only, much as the name "Content Locker" implies.

In April 2012 the decision was announced via Company memo that training was to begin on the iPad in spite of the limitations. Each pilot was directed to report to their home base of operation to their respective Flight Operations Office to receive their iPad. The pilots were directed to report off duty for an hour of unpaid iPad training. The initial training was deemed voluntary since the pilots would not be paid for their time. Given that most pilots live away from the base and only travel there for duty, and the unpaid training, only 55% or about 6,200 of the Company's pilots had drawn iPads and received training as of the end of July 2012. The company has distributed a directive memo stating all pilots must report for training by October 2012 since plans are for the federal restrictions to be lifted by then.

The Information Technology department and not Pilot Training conducted the training for the pilots. The training consisted of a review of the Company restrictions on personal use, prohibited websites, such as Facebook, limitations on personal email and notice that if the iPad were lost, stolen or damaged the pilot would be liable for the depreciated cost and the amount deducted from the pilot's pay. Training moved to an overview of the iPad physically, access to buttons, recharging and sign on. The user's manual was provided but not reviewed. The training did not cover any pilot concerns such as CRM, SA, flight planning, decision making or storage on the flight deck. The total training time was noted to be about 20 minutes consistently in subsequent interviews.

The training itself was hindered by lack of wireless access inside Company offices. Since the iPad must be initialized through a secure Company connection, and the corporate spaces did not have wireless, the first wave of training resulted in a show and tell with instructions to return for initialization at an unspecified future date. In the later part of April wireless access was installed and the iPads could be connected to the Internet during training.

The researcher was one of the first volunteers to receive an iPad. Being unable to initialize the iPad given the lack of corporate wireless access wasted a day's travel from home, on a day off, without pay. In the same group with the researcher were 17 other pilots. The lack of planning and coordination were noted in subsequent correspondence and interviews. On the researcher's first flight with the iPad to Monterrey Mexico, Mexican Customs officials seized iPad since only one piece of computing technology is allowed into Mexico per person, and the researcher was carrying his laptop as well. The iPad was held for three weeks while the Company coordinated release and return (Senior Flight Manager, personal communication, May 14, 2012).

Survey Results

The purpose of the survey phase of this exploratory study was to use the UTAUT from Chapter 2 to understand and describe the pilot's behavioral intention to adopt the iPad for cockpit use. The UTAUT model provides understanding of perceptions of the social and management support for the implementation as well as assessment of the effectiveness of training received. The UTAUT model was used to understand the pilots' performance expectancy or the degree to which the pilots believe using the technology will assist in the attainment of gains in operational performance. As described in Chapter 3 the UTAUT model has a high level of reliability and has been a consistent predictor of technology acceptance in a variety of situations.

UTAUT also provides indications of the effort users expect to expend in use. The model suggests that the more difficult the system is to use, the less the technology will be used. The third antecedent to use within the model is the social support the user expects to receive from managers, trainers and colleagues. If the training is seen as deficient, or colleagues indicate a lack of usefulness, the models suggest the system will be less used. The literature review revealed that the concept of performance expectancy is the most powerful tool for explaining the intention to use the new technology, regardless of the type of environment as seen in mandatory or voluntary application. Low scores in training, social aspects, and ease of use would suggest low performance expectancy for the survey results. Table 1 provides a summary of the 147 surveys received.

Given the exploratory nature of the study and introductory concept of iPads in the cockpit descriptive statistics were used to describe data from the questionnaire. Primary attention was given to the mean score as an indication of pilot response and perception. A simple but insightful tool to use for descriptive statistical analysis is the Pareto Method (Juran, 1980). The Pareto Method, also called 80/20 analysis, was used to select data that gave insight into pilot's Performance Expectancy, Effort Expectancy and Social Support as indications of Intentions to Use the iPad. As stated in Chapter 3 the survey is intended to assist in the development of understanding and not to function as a tool for detailed

Table 1

Survey Results

	Strongly Disagree/1	Disagree/ 2	Neutral/3	Agree/4	Strongly Agree/5	Mean	AVG
Performance Expectancy							
I find iPads useful in the performance of my flight duties.	36	12	14	78	7	3.05	
Using iPads I can accomplish tasks for flight operations more quickly than paper charts and manuals.	7	11	5	36	88	4.27	
Using the iPad increase my productivity in flight.	9	32	67	30	9	2.99	
Using iPads enhances CRM	21	16	74	22	14	2.95	
Using iPads enhances SA	4	6	5	101	31	4.01	
							3.45
Effort Expectancy							
My interaction with the iPad is clear and understandable while engaged in flight operations.	31	41	17	58	0	3.90	
It is easy for me to become skilled at using the iPad in flight operations.	11	49	17	58	12	4.33	
The iPad is easy to use	8	11	3	78	55	4.26	
Learning to use the iPad is easy for me	3	16	11	101	16	3.76	
							4.06
Attitude Toward Using							
Using the iPad to replace paper manuals and charts is a good idea	0	18	19	41	69	4.10	
The use of iPads in flight makes operations more enjoyable.	17	13	65	32	20	3.17	
							3.63

(Continued)

	Strongly Disagree/1	Disagree/2	Neutral/3	Agree/4	Strongly Agree/5	Mean	AVG
Social Influence							
The union I belong to has been supportive of integration of iPads into flight operations.	11	32	73	21	10	2.91	
The airline management has been supportive of integration of iPads into flight operations.	45	51	23	20	8	2.29	
My colleagues have been supportive of integration of iPads into flight operations	14	16	19	55	43	3.66	
The airline's training department has been supportive of integration of iPads into flight operations.	78	32	11	13	13	1.99	
							2.71
Facilitating Conditions							
I have the knowledge necessary to employ the iPad efficiently in flight operations.	55	24	21	27	20	2.54	
The company provides necessary support to use the iPad.	47	54	9	23	14	2.34	
							2.44
Self-Efficacy							
I can complete most tasks needed for employment of iPads if there was no one around to tell me what to do.	24	46	21	33	23	2.90	
Behavioral Intention							
I intend to use the iPad in flight operations as often as possible	35	18	7	41	46	3.31	
I intend to explore additional applications for the iPad in flight operations.	65	32	18	30	2	2.13	
							2.72

quantitative analysis. The data was studied to seek digressions from mean scores of the Likert scale as indications of pilots' perceptions and as a way to refine interview questions.

The data were studied from the perspective of a mean score for each question asked. Pareto's Method suggests that 80% of relevant information comes from 20% of the collected data (Juran, 1980). This approach was used for an initial exploration of 20% of the highest and lowest mean results from survey questions. The intention was to see if themes resulted to give insight into a particularly high or low return and impact on Performance Expectancy, Effort Expectancy or Social Influence. These insights were then used to modify interview questions and focus conversations during the interview phase. Given the 20 questions on the survey the Pareto Method suggested studying the four high and low mean scores for analysis. The survey had been distributed as described in Chapter 3 over April and May of 2012. One hundred and forty-seven surveys were returned using a web-based function. Company data over April and May showed that 1,748 pilots out of 11,000 had drawn iPads and received training. The analysis began with the four high scores for specific questions from the UTAUT model-based survey. Table 2 summarizes the four highest responses on the survey while Table 3 shows the four lowest.

The UTAUT model holds that the four key components of Intention to use technology are Performance Expectancy, Effort Expectancy, Social Influence and Facilitating Conditions (Venkatesh et al., 2003). Looking at the results from the Pareto Method as advocated by Juran (1980) shows that the pilots expect the iPad to improve performance while being easy to use. However, they also perceive a lack of support from managers and the training systems in preparation to use the iPad in operational flight. This qualitative analysis suggests that pilots expect the iPad will increase the effectiveness of operations, but that the pilots lack sufficient support in the form of technical training and organizational technical effort to bring those expectations to fruition.

Table 2

Four Highest Responses

Survey Question	Expectancy of Use Antecedent	Mean Score
Using iPads I can accomplish tasks for flight operations more quickly than paper charts and manuals.	Performance Expectancy	4.27
The iPad is easy to use	Effort Expectancy	4.26
Using iPads to replace paper manuals is a good idea	Attitude towards using	4.10
Using iPads enhances SA	Performance Expectancy	4.01

(*continued*)

Table 3

Four Lowest Responses

Survey Question	Expectancy of Use Antecedent	Mean Score
The airline's training department has been supportive of integration of iPads into flight operations.	Social Influence	1.99

Survey Question	Expectancy of Use Antecedent	Mean Score
I intend to explore additional applications for the iPads in flight operations.	Behavioral Intention	2.13
The airline's management has been supportive of integration of iPads into flight operations.	Social Influence	2.29
The Company provides necessary support to use the iPad.	Facilitating Conditions	2.34

The survey results indicate a high level of Performance Expectancy and Ease of Use as defined by Venkatesh et al. (2003). Similarly the survey indicated dissatisfaction with the training received and the managerial support for the implementation of the iPads. The literature from Chapter 2 indicates that for the pilots to use the technology they had to first accept the technology, which requires training to ensure ease of use (Venkatesh et al., 2003). Kirkpatrick and Kirkpatrick (2006) note that for an organization to realize the long-term benefits of any training program the training must be recognized as having changed the behavior of employees so as to have become part of the new cultural norm for operational improvements.

Though the survey identified training deficiencies limiting intentions and capabilities for use, the pilots also responded positively for the future potential for improved CRM and SA. The opportunities identify improvement potential for both the efficiency of the business as well as the safety of passengers.

Using the results of the surveys coupled with the literature review from Chapter 2 provided for the development of these interview questions. The broad themes for the interview questions sought to understand the impact of training, the support for the implementation from the Company's managerial staff, future disruptive capabilities of the technology relative to productivity, potential improvements to CRM and SA. The interview questions for the semistructured interviews coupled with the supporting reasoning for the selection of the questions follow:

1. How did the training received prepare you for the use of the iPad in flight? Based on the work of Kirkpatrick and Kirkpatrick (2006), the basis for training impact on organizational improvements is the quality of the training received. Use of the iPad depends on the training and each of the research questions relies on use of the iPad. Venkatesh's (2000) work shows that absent training the user will not accept the technology given expectations that the systems will not be easy to use. The UTAUT model survey results gave the low marks to the training.

2. What ideas did the training provide about how to improve operational productivity? The survey results show that pilots see great potential or Perceived Usefulness from the iPad. Each of the research questions seeks insight into the potential improvements for efficiency, CRM, SA and expanded capabilities. Christensen and Raynor (2003) emphasizes that technology that meets a "job" or specific user requirement coupled to a network of other users and one that is a lower cost entrant to the market creates a disruptive opportunity to the new entrant. The "job" of the technology must be the one that the user has in mind. The training for the technology must be centered on the anticipated "job" the technology will fulfill.

3. How well did you feel the Company's management supported the initial implementation of the iPad? The survey results show a very low score for managerial

support. Venkatesh et al. (2003) have found that managerial support is a key indicator as to Social Influence. The survey revealed that the managerial support received the lowest score of 1.99. Absent Social Influence the Behavioral Intention will negatively impact the Intention to Use.

4. How can the iPad improve CRM? Weiner (1988) emphasizes that technology must have a defined role inside the cockpit. Absent clear boundaries for use the technology may interfere negatively with crew coordination and communication rather than improving upon CRM. The survey's highest score of 4.27 shows that with the iPad cockpit resources will be better managed and tasks will be executed more effectively.

5. How can the iPad improve SA resulting in safer, more efficient flight operations? The end result for any addition to cockpit procedures as emphasized in the literature by Endsley (2010) is enhanced SA. As the high score on the survey attests, pilots anticipate the iPad has the potential to dramatically enhance the SA for pilots. This is the "job" as described by Christensen et al. (2004), Christensen et al. (2011), and Christensen et al. (2009) that the pilots seek for the technology to do by providing networked accessibility to the knowledge available through connected sources.

Interview Results

Table 4 provides the background for the interview participants. As described in Chapter 3 all participants were voluntary and had participated in the initial survey. The interviews were conducted as described in Chapter 3. The background of the pilots indicates a high level of experience as measured in both years within the profession and as measured by flight hours. Where relevant the academic background is included to give insight into familiarity with human factors and technology in aviation.

Table 4

Pilot Demographics

Pilot	Flight Deck Position	Type of Flight Training	Flight Years	Flight Hours	Aircraft Types	Education
	Captain	Civilian	30	18,900	727, MD-80, 737	BS Aviation
B	First Officer	Air Force	24	11,500	A320, 737, 757, 767, C-130	BS Human Factors, MS Human Factors
C	Captain	Army	31	15,500	AH64, DC-8H, ERJ 145, 737	BS Aero Technology, MS Aerospace Engineering
D	Captain	Civilian	35	21,000	727, MD-80, 737, ERJ 170	
E	First Officer	Air Force	25	6600	C141, C17, A320, 737, T-38	MS Operations Research
F	First Officer	Air Force	21	5500	C130, C17, 737, 757, 767	AF Test Pilot
G	Captain	Civilian	17	9000	ERJ 145/170, 737	BS Aviation
H	Captain	Navy	22	11000	F/A-18, 737	
I	Captain	Civilian	31	14,000	727, MD-80, 737	
J	First Officer	USMC	17	12,000	AV-8, 737	
K	First Officer	USMC	19	12,000	AV-8, 737	
L	Captain	Air Force	30	14,000	KC-10, 757, 767, DC-10	MS Human Factors and CRM Instructor
M	Captain	Civilian	20	17,000	ERJ 145/170, 737	

None of the 13 pilots interviewed characterized the implementation of the iPads as well managed, conceived or successful. The researcher found the general pilots' reaction summarized by Pilot D when asked how he would characterize the implementation. Pilot D, though flying operationally, was also assigned to corporate headquarters working on coordination with the FAA on iPads and other matters. He responded that the implementation was:

> to be frank, abysmal. Remember corporate decided this was an IT project, not a matter for Flight Standards to lead, so it was seen on the same level as a laptop refresh. As a result pilots were executors, not planners or even asked for input that I saw.

The other 12 pilots responded in similar fashion but without the insider insight generally using terms like “worthless,” “poor” or “wasted.”

Analyzed for recurring themes the interviews resulted in three trends and topics that derived from the interview questions. The first theme related to training and the lost opportunity for any efficiency gains with the introduction due to a lack of situational training for pilots. The pilots tended to note a lack of applicability between the iPad and the flight operations other than as a document retrieval source. Policies limited the ability to experiment so the initial use for the iPad was limited to searches for documents. Given some installation problems with the content, pilots often found it easier to look up the information in familiar paper documents. As an anecdote, the researcher has flown operationally for four months and has only witnessed two pilots use the iPad in flight.

The second theme the interviews uncovered was that the failure to consult pilots created a barrier to integration into daily operations. Interviews showed pilots had definite ideas about how iPads could be used based upon experiences and imagination but since their inputs were not solicited, and since experimentation with new applications or during flight operations were not allowed, the pilots did not volunteer ideas nor were they solicited by the training personnel after the initial training.

The third theme was that lack of connection to an Internet or information technology system created a perception that there are limited productivity opportunities with the current state of affairs. The iPad, absent connection to an information sharing system, stores documents and is capable of performing operational calculations such as weight and balance or fuel planning. Operational threats and opportunities are not available because outside information cannot be acquired. Company policy prevented the iPad for being used for the operational calculations so even when Internet sources are available, such as inside the airport, capabilities cannot be used. Other information sources, such as real time weather updates are not available either. This connectivity limitation created a difference in the theme of perception between managerial intent and user observation of potential opportunities. The managers saw the iPad as replacing content, even calling the documents stored on the iPad the "Content Locker." Pilots saw productivity gains by being able to use the resources to calculate faster and plan better. Pilots also perceived the opportunity to create "360-degree" SA with the iPad, as the ideas were repeatedly called in the interviews. The iPad, when connected to an Internet source can really see the whole world. Pilots within a cockpit currently can only build SA based on fragments of verbal or textual data provided by controlling agencies that perhaps extends out several hundred miles, when coupled with available aircraft systems.

First Theme: Training

All 13 pilots continued upon the theme of deficient training from the survey. Each pilot described a similar process of training focused upon switch use with a heavy emphasis upon prohibited activities articulated in extensive corporate policies. The training did not integrate the iPad into flight operations and pilots felt the training was absent context or practical meaning.

Pilot C relayed a common theme when he said "we need training and procedures like any other piece of flight gear . . . hell we get an hours worth of training on how to use a crash axe to open windows." Pilot B built upon this idea by saying, "Here we are treating the iPad like a piece of office equipment rather than flight deck technology."

The frustration Pilots A, B, E and H had to do with the use of the IT department to lead the integration and training, instead of the Company's Pilot Training Center. Pilot E noted that he has worked in the IT field for a defense contractor during a furlough, as well as the military when he was on active duty. He has a masters' in Operations Research and a bachelor's in computer science but emphasized that he had never used an Apple product and was unsure of how the system fit into flight operations. He stated:

> They handed me the box and said use it! Standard IT mentality of build it and they will come. I don't feel qualified to use the thing in-flight. First they scare the hell out of us by telling us we'll get fired for going to the wrong site so I've got zero incentive to play around with it. I can't see any way I can call this a cockpit resource without understanding capabilities and I'm afraid to play with the capabilities until someone tells me what I can do with it.

Pilot F has had significant use and experience with the iPad as part of the Air Force's integration effort of iPads into military transport and cargo operations. His experiences were the opposite of those noted by those with only experience at the Company. Pilot F stated:

> We turned the project over to our aircraft's type weapons and tactics team for the C-17. They put together a training program based on inputs from operational pilots, Apple, instructor pilots and weapons' systems developers from industry. They talked to human factors experts at Wight Patterson AFB for outside opinions. Once we had a plan, once we knew how the iPad could be of benefit,

> the Air Force went out and bought almost 20,000 and with that plan they are in use all over the world now doing everything from weather updates, load plans, engine calculations and pilot training updates.

Pilot L, who also has experience with the Air Force, continued on the opportunities shared learning with other organizations offer relative to training:

> I've flown C-141s in the Air Force on active duty and with the reserves for 25 years. Say what you will about how anal the military is but no one uses technology in the cockpit until they are trained to do so. With the training people figure out why use is important and also opportunities, along with confidence to use the technology. In the Air Force there would be at least one pilot, if not more, in charge of answering questions after the training so I could call for help. Not only was there no training but no follow up pilot I can ask for guidance real time. If I do call I get the IT help number with the standard connection to India.

Pilot I responded that the training was absent relevancy to the context of flight operations. He said:

> Make the training related to the work the Company wants us to do. People don't learn from a couple screen shots in a manual. They learn, especially pilots, when they get to use the tool on the job and then have someone available to help understand mistakes or misuse. They hand me the iPad and then ask if I have any questions. I've never owned an iPad—I use a Droid, my computers at my home and office are HPs, but I'm supposed to just know. It isn't intuitive and no one is paying me to learn how to use it. I get a user's manual handed to me so in order for this thing to make sense I have to take my own time away from flying or my side business and learn how to use it. Then I can't use it anyway because I'm unsure of the flight regulations. Like always the Company doesn't have a clue . . . they just pronounce on high and expect it to work.

When asked how Pilot I would improve upon his current experience he said "Make the training part of pilot training. Put people in a simulator and let them use the iPad as part of a line flight, not some office work."

Pilots J and K both described training as "nil." Pilot K was very explicit given his background as a weapons and tactics training officer from the Marine Corps while flying AV-8 Harriers.

> Management is clueless as to how important an hour's worth of training in use can overcome so much resistance. I mean if we look at paper manuals we index by chapter, then page, then paragraph. So we've been trained since day one with the company to know that engines are under chapter three, emergencies are on page 20 and so forth. Did you see how they set the iPad up? Instead of pages they index by paragraph number with the last number indicating aircraft system. That means they should at least be thinking about simple things, like teaching pilots there is a new way to look stuff up.

Pilot L, when asked what role training had to do with her view that the iPad implementation has been a failure responded:

> I was shown how to turn the iPad on and then how to log onto the Company website. Then I was told about how I'd get in trouble for visiting the wrong sites or downloading apps. We didn't even have Internet access for the training. Instead the instructor showed us screen shots . . . but out of a good faith effort I've been trying. I have not found our material intuitive, and to be blunt, follow up responses to my questions on use have been garbage. Standard though. The Company does everything on a shoestring, if they think they can save a dime the accountants run after the cheapest solution, never think about involving the people doing the work and then threaten people if anything goes wrong. I stopped trying after a month and just use the old paper and office computers. At least I know how to use that stuff.

Second Theme: Lack of Solicitation of Pilot Input Limited Productivity Gains

Current use of iPads in flight operations by pilots is limited to content retrieval. Because the FAA has not rescinded the requirement to carry paper documents the expected fuel savings due to decreased weight has not been realized. Company memos have noted that the paper is still required because the FAA still has concerns as to the training, use, storage and durability of the iPad in flight operations. The iPad, though capable, is not being used to perform flight performance calculations such as fuel planning, weight and balance and flight profiles. These performance calculations are still being done at corporate headquarters with time delays given transmission via radio means to the flight deck of each aircraft. Similarly, weather forecasting for flights is done at a central corporate location and is provided to pilots before flight via the corporate desktop system.

The centralized planning and decentralized execution causes logistic challenges for pilots in large airports. Access to corporate computers is only available at a few office locations at major airports so pilots must walk from their aircraft, to a corporate office. The information is downloaded and printed onto about 50 sheets of paper for each flight. Even though iPads are able to download this information, the physical requirements exist causing pilot's to walk from one side of a large terminal, such as Terminal 7 at LAX, to Terminal 6 in order to retrieve flight plans.

When questioned about the productivity or efficiency improvements that have been realized with the introduction of the iPads, all 13 pilots responded that company policies, limiting the iPad to content only, while requiring pilots to still carry and maintain their flight bags, has not created any benefits. Most statements noted the disconnect between the managerial focus upon content as compared to the pilots' focus upon productivity improvements and better manage resources on the flight deck. Most responses were story based, relaying what might have happened if use of the iPads was allowed in operational situations that needed rapid answers.

Pilot A noted that when the physical bags are replaced, the expected savings in fuel costs would result along with "the rapid ability to look up emergency procedures will result in safety increase during emergencies." He continued:

> but I wonder about how we can use the iPad for things that seem so wasteful now, such as late push backs from the gate while the Company struggles to get us takeoff calculations. The iPad has that ability or capability to do the math but we have to send a radio request to the airport ops center to send a message back to the company before we can get the data . . . so every time the barometric setting changes a few inches we have to wait 20 minutes and get later and later.

Pilot B noted that based on his experience in the Michigan Air National Guard C-130s, traditional flight-planning times could be significantly reduced.

> Instead of printing 30 or 40 sheets of paper with our flight plan since the computer monitors they give us are so hard to read, we download all the data to our iPads and then use an app to plot our route on a map. We get understanding at a glance as to our route and the weather, enemy threats if that's pertinent and the weather or divert fields, what have you. As it is now at the Company we are limited to paper, absent even a picture of where the weather is along our route of flight, unless we go by one of the Company's weather maps put up for passengers. We have to manually plot our route followed by drawing the weather in given the data . . . what takes us a half hour iPads are doing in seconds . . . then in the Guard we download our takeoff data. The funny thing is we in the Air Force and Guard have always done our own takeoff calculations to save time yet a big commercial company spends millions with some central office that is a bottleneck for our operations. Who does a better job the? The guy in the plane or the planner sitting at his desk drinking coffee? Let the pilots manage their own cockpit.

Pilot C noted that the iPad is:

> now a game-changing piece of gear that is being wasted by not using pilots as a source of information about better ways of operating with it. Our on time rate for pushback has to be terrible due to weather reroutes, yet I can't call up weather on my iPad since the app is prohibited, but I can do it on my iPhone, but I refuse to use my cell phone to help enable the Company's managerial incompetence. Instead I call the company from a landline inside the terminal and have them fax me a picture or tell me over the phone what the dispatcher says the weather looks like. Look at how inefficient we were today. I'm in San Juan Puerto Rico. I went to the company office to get the flight data. I'm trying to print 41 pages of documents on the other side of the airport from my gate and the printer breaks, it is Sunday morning. It takes me 30 minutes to find someone that knows where another printer is. Finally I give up and find a fax machine and the dispatch crew (note: the operations center from corporate headquarters) has to fax me the documentation. It's like it's 1980 here everyday. So the other pilot and I hustle and we get the aircraft airborne a few minutes' late buts that how accident chains start with those crazy, last minute heroics. This isn't efficient crew resource management.

Pilot E had significant experience in information management when he was on active duty with the Air Force. He related the efficiency and productivity theme to what information managers call a capability maturity model. Managers for information technology projects use the capability maturity model to create a measure of an organization's readiness and motivation to use a technology in daily activities (Researcher's note: as defined by McKeown, 2003). Pilot E explained that the more beneficial the technology is to an operation, the more useful the system to the productivity of the operation. The capability model assesses an organization's acceptance and application of technology and the capability of that organization are assigned a level. He noted a low level of maturity, a level one score, comes when an organization uses an ad hoc implementation with limited acceptance by the rank and file. Level two is acknowledgement that the technology exists but limited use, usually due to lack of training. Level three comes when processes exist to use the technology but the use is forced by management rather than acknowledged as beneficial by workers. Level four has a workforce that accepts and uses the technology but the use is a choice. Level five comes with automatic, universal acceptance or the technology has become part of the daily culture. The levels are assessed based on daily use of the technology.

Pilot E used the analogy of cellular phones in the United States as an example of Level Five maturity, while some office products, like Microsoft Project, are at Level Two. Pilot E characterized the current state of iPads at the Company as:

> maybe a level 1.5. At this level, there hasn't been adequate training to create acceptance so there really isn't any use that creates meaning, no resource for the crew to manage since no manager solicited our input . . . I mean I don't even carry mine, my daughter uses it at home . . . such a low level mans there won't be any productivity since the use itself isn't natural. At this stage technology tends to die since no matter what mangers do people just see more trouble that benefit.

Pilot F told a story about misplacing a paper chart that he needed to land with containing maneuvering instructions for Boston's Logan Airport. Normally when this happens the two pilots in the cockpit share the available chart. Unfortunately, in this case, the other pilot had misplaced his as well. Pilot F, not thinking about Company and policy restrictions concerning use of iPads below 10,000 feet, used the iPad display. As he said:

> the display was awesome. We could see the display clearly with limited cockpit lighting even though it was past midnight. When we figure out how to use this it will be great. The screen was adjusting to the low light, there was no glare, and we could zoom in and out, just perfect. I mean, what was my choice? Have someone read me the approach and then fly it with a hand drawn map based on what I'm told over the radio?

Pilot G, in regard to efficiency gains, stated:

> I don't see any gains since crew resource management hasn't been involved at all . . . the iPad is a really well designed paperweight. I'm still lugging 50 pounds of paper and replacing outdated forms every two weeks so I'm not seeing any advantage in the technology. . . . We did this knowing the iPad we bought was already a generation behind, some bean counter probably thought we got a great deal, this is standard Company incompetence. Buy old technology just to replace documents and never ask a pilot how to take the greatest advantage of the idea.
>
> I do love downloading my newspapers and magazines though it is against Company policy. What are they going to do, fire me for reading *Sports Illustrated*?

Pilot H provided notable insight since he manages much of the pilot training in aircraft systems for the Company. He is a senior manager, at the Director level, and directs a staff of over 200 pilot trainers and systems experts. He emphasized that he had not been consulted prior to the implementation and because pilots were not consulted one would not expect to see much improvement. In his words there was:

> no coordination between the reality of getting technology into the cockpit given government oversight from the FAA, where saying no to everything is the first and easiest step, with including what pilots need to ensure the technology gets used in flight. Given that, we'll be carrying the paperweight for another year.

Pilot K said:

> I'm trying to use the tool but between a company IT policy that limits access from downloading apps that are designed for improving flight ops to FAA rules about not using below 10,000 feet to my own fear that I'll lose or break the thing and have to pay $500, there just isn't an easy way to experiment and see if I can come up with new ideas.

Pilot L placed the emphasis upon not managing the integration as a pilot, would by making the iPad a real part of the aircraft system and installing it as a Class 3 EFB as noted in Chapter 1. An EFB is fully integrated as part of the aircraft computer systems. Pilot L noted there are other airlines moving in this direction:

> Maybe if this was a full up Class 3 EFB like some versions on the Boeing 777 or the ones FEDEX, JetBlue and Southwest uses . . . things would be different . . . but when ideas aren't properly played out and the folks using the gear have no input as to how the gear should be used, no contingencies considered and the right amount of "what ifs?" asked management shouldn't be surprised to find out the iPad isn't being used as a resource and the productivity payoffs don't come. I'm sure given the history of the iPad efficiencies and apps will come along but as of know, there is no system to it and the only thing I look forward to is not having to update my publications manually every 2 weeks.

Pilot M gave an example of the missed gains in resource management and productivity:

> Last night in Leon Mexico thunderstorms had moved in around the field. Leon's tower doesn't have weather radar so I have to call our company and have them fax me weather pictures. But guess what? The Company's pictures are in black and white and the fax machine has a terrible time breaking out the shades of gray highlighting the densest clouds, so I end up with a couple pages of black blobs that are worthless. Here I am with 150 lives at stake on my decisions and I have to try to figure out what are thunderstorms and what are mountains. Safety is always first in our minds so I don't want to takeoff without being absolutely sure. My weather radar will be great once I get airborne but I want to be sure I'm not taking off into a bad situation right off the runway. My iPad doesn't have a cellular connection and there is no wireless at Leon's airport. So even though I can get wireless there is none available.
>
> But using my own personal iPhone with the weather app I can see everything going on. But I know the international roaming charges will cost me an arm and a leg plus the Company won't reimburse me for it. Now do I takeoff based on my iPhone, an unauthorized piece of gear or do I sit and wait with 150 upset passengers until I'm sure? The union and company both say safety first so we sit and wait for 45 minutes until I can visually see the storms are clear. Meanwhile passengers with iPhones watch the weather clear out a half hour before my eyes tell me it is safe and I have to listen to them complain about missed connections in LA. Where is there anything remotely efficient in this story?

Third Theme: Future Opportunities

The interviews revealed a high sense of optimism for future applications of the iPad technology and enhanced flight operational performance. The bottleneck for this growth was seen as connectivity to an Internet source. Currently there are plans on hold to install Internet and wireless capability on commercial aircraft at both the Company and other major airlines. Some airlines, such as Southwest and Virgin American have installed Internet on the majority of their fleets. At the Company, some of the larger, transoceanic aircraft have been configured with Internet but the vast majority has not. Each interviewee identified the Internet as an absolute requirement for iPad maximization.

Currently data are communicated between commercial airliners and ground stations with a system called the Aircraft Communications Addressing Reporting System or ACARS. The system is a commercial, for profit venture by a firm, AIRINC. ACARS has been in operation since the 1970s and uses very high frequency radio transmissions over ground stations and satellites to relay data to and from the aircraft. The data link message types are rudimentary textual transmissions that can be printed on the aircraft printer. The messages detail weather reports, basic company communications and maintenance status. If one thinks of a 1980s computer screen condensed to a 6" x 6" screen attached to a dot matrix printer, the general technological capability can be realized. ACARS does not have the capability to interface with the iPad though with modification could do so.

The FAA is developing a Next Generation Air Transportation system, known as NextGen, for implementation in 2014 upgrading the nation's air traffic control network to

21st century technology. Part of this technology will be a web enabled communication system via satellites and ground stations allowing Internet-like connectivity for the iPad, if aircraft are configured as such.

This theme of connectivity identified a basic perceptual difference between the intended application of the iPad from a management and IT perspective as compared to the opportunities that pilots perceive. Managers and IT saw the iPad as a way to store content. Pilots perceived the iPad as a way to enhance productivity and build superior SA with the power of the iPad as a crew resource. Where management and IT perceived the iPad as a way to store and retrieve explicit knowledge, the pilots view the iPad as a way to share tacit knowledge building better SA. The term “360-degree SA” was used by 11 of the 13 pilots interviewed as an example of the desired end state. If one thinks of current SA as being limited to what pilots’ eyes can see, coupled with what mental pictures the pilots can build from radio reports that extend out to perhaps 250 miles, coupled with the textual transmissions through ACARS, a pilot currently has perhaps “180-degree SA” out to several hundred miles. With connectivity, the iPad can depict real time weather, traffic, threats and emergencies unfolding any where on the globe. This is what the interviewees meant with the term “360-degree SA.”

Uniquely, Pilot A thought the iPad had limited opportunities to be integrated into the larger system. He saw the iPads technological capabilities as a:

> generation ahead of what commercial airliners carry due to delays and incompetence by the FAA in accepting best in class technologies. The speed of the iPad is 21st century and except for maybe the 787, our aircraft use computers designed in the early 1990s, at best.

His perspective was unique given that each of the other pilots emphasized the possibilities with integration of the iPad into aircraft systems as an EFB 3 and as a stand-alone crew resource when connected to the Internet.

Pilot B gave several examples of capabilities he is currently witnessing as an Air National Guard pilot as a C-130 pilot.

> Our SA is up big time. We've integrated the iPad into our SATCOM (satellite communications) systems so we get real time updates worldwide. It was a simple plug into one of the aircraft communication buses and then connection to the iPad. Took some engineers about 15 minutes to figure out so now we have a 40-year-old C-130 with better SA and visuals than a brand new 737. Our C-130s get real live video showing what the special ops guys are seeing on the ground, or what is going on at our airfield half way around the world. This way if we are on our way to Afghanistan and want to see if the airfield is under attack we can find out. We can see the weather 1,000 miles out to plan ahead for fuel. I'm sure Uncle Sam is paying out the nose but it's worth it.
>
> The SA really grows with the information flow, we can see what the special operators see. They can give exact locations and we can see what they mean when they say by the hill or in the ravine so we can correlate real time.
>
> In the commercial world I see weather as the biggest threat we will be better able to manage with this resource. Maybe with a 737 weather radar we can see out 200 miles, at best, probably closer to 150. With the iPad and Internet we can use weather apps that can depict our whole trip. . . . This is a quantum leap in SA. Out of LA we will see what's developing for traffic flow into O'Hare. Now we can told about it 10 minutes out. With luck, now we see a tenth of what the iPad shows. We will make better decisions earlier, and with better SA save the company money because we'll be managing fuel and resources better. This is the resource management we need to build upon, threat recognition.

Pilot C spoke of the differences between the mental picture pilots build based upon the delayed and fragmentary information provided by company communications, air traffic controllers, other aircraft and historic trends. He said it is not uncommon for pilots to fly from one coast to the other and never receive an update on traffic congestion until checking in with the destination's local approach facility, approximately 20 minutes from landing, only to be told there would be an hour delay. This causes pilots to board more fuel for the unexpected and as he stated "it costs fuel to carry fuel so the Company isn't even accounting for this." He continued:

> Now we will better manage resources from outside and inside the aircraft. When we can connect to the air traffic system we'll really have the big picture instead of looking through a soda straw. I see taking off from Seattle and seeing real time the mess unfolding in Newark and being better able to plan fuel, inform passengers, manage airspeeds by being able to see developing pictures. . . . Imagine just throwing the question of "how can we better use this technology to fly safer and save gas?" to the pilots and see what sticks? Simple ideas like a moving map to track runway incursions on the ground could save lives. We are talking 360-degree SA.

Pilot D emphasized the integration of the iPad, the aircraft and NextGen air traffic management systems as the ultimate opportunity to create huge, system wide productivity improvements with reduced traffic separation, better airspeed management, reduced traffic delays and higher passenger satisfaction because of better travel. He said:

> I think the efficiencies will be particularly noticeable with the NextGen system . . . the FAA is actually leaning forward on this, strange as that sounds, and their planners see the transition moving from iPads as content, to productivity, to knowledge. I was at a presentation for airline officials by the FAA in May of 2010 and that was the exact flow used as they described iPads and other portable computing devices fitting into the system as in content to productivity to knowledge. I hope we can transfer the knowledge to SA for pilots and not just revenue for the Company. I don't know if this will require redesigning and reclassifying the iPad as an EFB 3 but the possibilities and capabilities are real.

Pilot D was then asked about the contents and background for the presentation he mentioned. Pilot D was able to retrieve the Power Point slides from the presentation he mentioned for further discussion. The slides were created by the Jeppesen Company, which is now part of Boeing and described in Chapter 1. The slides were focused upon the higher end of the EFB industry or the EFB 2 and 3 categories, those computers integrated into the aircraft as part of the onboard computers systems and costing significantly more. The concept as stated in the Power Point slides was to ensure the

EFB was used to provide real time updates via the NextGen air transportation system. There was no mention of iPads other than to note that the airlines were using the iPad as a low cost alternative to the more expensive EFBs.

Pilot E, with his academic and professional background in IT echoed these remarks by noting the iPad is really a "knowledge management system" and that "now we can take data, make it actionable, put it in context and exchange it creating knowledge . . . real time without delay and the mental puzzle pilots have been putting together for the last 50 years can get a real time boost." Pilot F continued with similar sentiments about replacing bits of radio transmissions with a real picture but emphasized that the Company had to start thinking connectivity, like the military, if they hoped to achieve pilots' 360-degree SA.

Pilot G remarked "the answer lies in connectivity, like with AIRINC but at least moving the capabilities to the 21st century. If we can connect we can share, and if we can share that info we can all get a lot smarter a lot faster." Pilot H saw potential in waste reduction, such as fuel wasted with holding or pilot time wasted printing documents.

> Now we can download on the go and instead of 50 pages of flight plans we can have it all on the iPad. Two iPads per cockpit ought to be reliable enough and if they did fail we could still get the data resent over ACARS. We'll have savings in paper and time. I have no idea where to put the iPad in the cockpit but it has to be easier to manage than paper piled up all over and getting in everyone's way.

Pilot H and L both noted the savings with updated courseware for recurrent pilot training. Now pilots are required to return to the training center and conduct 2 days of computer-based systems training. There are some allowances for Internet enabled training but face-to-face lectures are still required. Pilot H, who works at the training center, noted that there are best in class universities and corporations conducting a significant portion of their learning via distributed means and that there seems to be strong support because of reduced travel costs.

When Pilot H was asked how he envisioned using the iPad he thought use would grow to what he called "just in time training." As an example he noted that with video and audio capabilities the iPad could read off and describe checklists for the pilots. In emergencies, a pilot instructor could record common mistakes or errors so as the pilots worked through the emergency they could have guidance on switch positions, lighting, system anomalies and so forth. This idea could be a video depicting an instructor working through the emergency inside a simulator so pilots could watch, and then do, if time permitted.

Survey and Interview Results Summaries

The surveys and interviews both revealed the same themes. The survey highlighted that the pilots felt the training to be ineffective and the implementation of the iPad into flight operations lacked managerial support. The surveys also revealed that the pilots perceived great utility that would enhance SA when the iPads were properly integrated into flight operations. The integration would be best achieved with the inclusion of pilot input and training with the iPad integrated into flight training directed by the Company's flight training center.

The interviews highlighted three recurring themes the 13 pilots interviewed. The first theme is that training needs to be based upon pilot use and not upon what managers and technologists perceive the proper training entails. Training must be integrated into the job and there must be relevancy to the training. The second theme is that without training and managerial support for use in operations that did not anticipate policy delays from the FAA or take into account pilots' inputs for operational use, the intended flight efficiencies and cost savings were not achieved. The third theme is that pilots view the iPad as a productivity and knowledge source while management and technologists view the iPad as a way to carry content. Given connectivity to the Internet, pilots anticipate greater knowledge and information sharing achieving a much higher level of SA, greatly enhanced decision making and vast improvements to operational productivity because of use of the resource.

The first theme of poor training highlighted a basic difference in perspective between pilots as users and the managers and IT personnel. The professional pilots recognize the SA potential, which translates to knowledge while managers see efficiencies gained with content storage. The managers perceive success because content has shifted from paper documents to electronic means. The training was designed with that perception in mind, content management. Where content management leads to efficiencies, or greater outputs (such as profit) with reduced inputs (such as fuel), pilots are recognizing opportunities in productivity with better fuel planning because of route profiles that can be updated real time with inputs of new information leading into the next two themes. The pilots see improvements as measured by better routes, more on-time arrivals; smoother rides by avoiding turbulence and reduced delays. Pilots also recognize enhanced effectiveness by being better able to ascertain the proper course of action with enhanced SA brought about with connectivity via aircraft enabled Internet.

Chapter 5: Conclusions

Chapter 5 concludes the dissertation with a general discussion of purpose, a restatement of the research question, a discussion of results and recommendations for further research. The research has explored literature from the perspective of the creative destruction and disruptive opportunities at low cost. But capable, entrant into an established market offers. Specific to technology, certain conditions must be met to ensure user acceptance. Those conditions are ease of use, usefulness and social acceptance brought about by training the users in the context the technology applies to. Specific to flight operations, the intended outcome must focus upon improved quality of CRM and SA. As Kirkpatrick and Kirkpatrick (2006) emphasize, absent meaningful training the new systems will not create a benefit for the organization.

The survey instrument, based upon a TAM known as UTAUT, indicates the pilots recognize a great deal of potential in an iPad given the computational and connective capabilities. However the poor training received and lack of managerial support indicate the technology will not be used. The interviews with pilot users enforce and magnify the results of the survey.

Restatement of Purpose

This exploratory study intended to explore defined parameters of the introduction of tablet computers into the cockpit operations of commercial airlines.

Restatement of Research Questions

The general research question that this study will attempt to answer is "What opportunities and risk lay in the implementation of tablet computers for airline operations?" Specific research questions that guided the design of the study were:

1. What will be the impact of iPads on the efficiency of flight operations?
2. What will be the impact of iPads on CRM?
3. What will be the impact of iPads on SA?
4. What expanded capabilities might tablet computers bring to flight operations?

Participants

The voluntary participants in the study were all professional airline pilots who had attained the highest possible commercial flight rating, the Airline Transport Professional. The 147 survey participants had all received the Company's iPad training and had 1 month of operational experience with the iPad prior to answering the survey questions. The 13 pilots who were interviewed each had at least 1 month of operational experience along with the training provided by the Company considered necessary to use the iPad in flight.

Conclusions

Because of training that did not bring the iPad into practical application or draw from pilot experiences, there was a lost opportunity for any efficiency gains with the introduction due to this lack of situational training for pilots. The concept of the iPad as a storage system for content conflicted with the potential use of an iPad as a way to build greatly enhanced SA. The pilots viewed the Company's intended use of the iPad as a document retrieval source, this view was supported by the training and pilot observation of managerial intent. Policies limited the ability to experiment so the initial use for the iPad was limited to searches for documents absent experimentation for improved ways to operate the iPad integrated into flight operations. Given some installation problems with the content, pilots often found it easier to look up the information in familiar paper documents.

The failure to consult pilots created a barrier to integration into daily operations. Pilots had definite ideas about how iPads could be used based upon experiences and imagination but since their inputs were not solicited, and since experimentation with new applications or during flight operations were not allowed, the pilots did not volunteer ideas nor were they solicited by the training personnel. The lack of connection to an Internet information technology system created a perception that there are limited productivity opportunities with the current state of affairs. The iPad, absent connection to an information sharing system, stores documents and is capable of performing operational calculations such as weight and balance or fuel planning, but even the calculation productivity enhancements were not allowed. Operational threats and opportunities assessments are not available because outside information cannot be acquired without Internet access. Company policy prevented the iPad from being used for the operational calculations so even when Internet sources were available, such as inside the airport, capabilities could not be used. Other information sources, such as real time weather updates were not available either. This connectivity limitation created a difference in the theme of perception between managerial intent and user observation of potential opportunities. The managers saw the iPad as replacing content, even calling the documents stored on the iPad the “Content Locker.” Pilots saw productivity gains by being able to use the resources to calculate faster and plan better. Pilots also see the opportunity to create greater SA with the iPad as a result of enhanced CRM and Threat Recognition. Pilots within a cockpit currently can only build SA based on fragments of verbal or textual data provided by controlling agencies that perhaps extends out several hundred miles, when coupled with available aircraft systems. The pilots felt that once the connectivity challenge is resolved that enhanced SA will create the gains in productivity and operational performance.

Restatement of Findings by Research Question

1. What will be the impact of iPads on the efficiency of flight operations? There was none perceived by the pilots as recorded in either the survey returns or the interview themes. The reason for the negative responses had to do with the lack on Internet connectivity, the Company's focus upon content rather than knowledge and the poor design of the training, along with policies inhibiting experimentation. Once the connection to the Internet is applied and pilots can begin using the iPad as an information-sharing source the opportunity for improvements will be realized. This will require integration of a pilots' training perspective coupled with intelligent review of policies that view the device as content only. The training, policies, pilot incentives and structure of use must be realigned to move from content to knowledge sharing.

2. What will be the impact of iPads on CRM? The current policy state limits the iPad as a resource and enhancement of better resource management. Integration of the iPad into simulator training, using the iPad in the training environment and allowing experimentation will enhance the utility of the iPad in flight operations. When coupled with Internet connectivity the potential exists to use resources from across the Internet and increase opportunities for flight efficiency.

3. What will be the impact of iPads on SA? Connection to the Internet will transform the current state of content management to a future state of information and

knowledge sharing. This desired future state will require a change in technology with Internet access, policies allowing use of the iPad in more flight regimes and better pilot training to bring use of the iPad into application as a knowledge-creating device rather than content management.

4. What are the expanded opportunities that are possible with the iPad? Along with the enhanced SA given connection to the Internet there is the ability to move the current media, text based, to a video and audio form. As noted by several interviewees, the iPad can allow demonstrations of pilot activities during emergencies that allow an experienced instructor pilot to guide the pilots experiencing the emergency through the procedures. This is a form of "just in time" training that takes advantage of the iPads multimedia capabilities.

Summary of Findings

The research uncovered a supporting relationship with the literature review. For training to be meaningful, the perspective of the adult experiential learner must be taken into account, the training must build upon current knowledge of the user and the training must have relevance to the work the adult learning engages in (Kolb, 1984: Knowles, 1990; Knowles et al., 2005). For the training to be of benefit to the organization producing savings and improvements the training must be effectively adapted into day-to-day activities by the user because the training improves work performance (Kirkpatrick & Kirkpatrick, 2006). When related to technology, if the training is not based on adult experiential principles and not seen as beneficial by the learner, the technology will not be adapted for use by the intended audience (Davis, 1986, 1989; Fishbein & Azjen, 1975; Venkatesh, 2000).

This breakdown between what trainers or managers perceive as the function or "job" the technology is supposed to do and the "job" the user or customer sees the technology accomplishing prevents a technology from becoming a disruptive innovation (Christensen et al., 2004; Christensen at al., 2011; Christensen et al., 2009; Christensen & Raynor, 2003). The "job" as seen by management is rarely the one the user chooses to use the technology for. The same authors emphasize the role technology has to create disruptive innovation. The technology commodotizes knowledge as the technology enables networked exchanges of information. Absent the network, the disruptive element is limited to a single user rather than an entire organization. In order for companies to enable the benefits of disruptive innovation they must "creatively destroy" the policies, procedures, systems, markets and products that limit the potential of the new way of doing the work (Schumpeter, 1975). The literature shows the chain of training causing acceptance then motivating use and then creating disruptive opportunities because of unique "jobs" developed. But the training received is dependent upon the "job" the technology is designed to fulfill in the customer or user's work. Absent clear understanding of the "job" training will lack relevancy, the users will not appreciate the potential, the technology will not be accepted or used and the organization will not realize the benefits.

In the case of the iPad introduction the training did not take into account the lessons from adult experiential learning as stated by Kolb (1984), Knowles (1990) and Knowles et al. (2005). The training did not include the pilots' daily activities in work and the training was absent relevancy to flight activities. Additionally, the training did not draw from pilot experiences or ideas as to how best use the iPad in flight. The training was on function and not application to the work environment. Further corporate policies limited experimentation so pilots could not learn by doing as needed with adult experiential learning stated by Kolb. Without acceptance of the value of the training pilots did not feel there was worth and the system has not proved its training effectiveness with acceptance and savings as required by Kirkpatrick and Kirkpatrick (2006).

Though pilots recognize potential, the support and influence from managers and trainers as seen in policies and a training focus on content has limited the intention to use as described by Davis (1986), as well as the ease of use developed in Venkatesh (2000). The iPad has become a "paperweight" as described by 9 of the 13 pilots interviewed. In order to realize the potential of the disruptive technology the perceived "job" the iPad is intended for must shift via policy and managerial perception. The "job" as defined by Christensen (1997) is to use a lower cost, easier to use technology to meet an unfilled need in a equally productive manner. The pilots see the iPads job as building SA with networked internet connection creating rapid sharing of real time situations, exactly the "job" a disruptive technology should fill according to Christensen et al. (2002). In order for the Company to realize the potential productivity improvements that the pilots forecast, the Company must creatively destroy ideas on technology use, training, policies, roles and behaviors aligning the managerial view of the "job" with the pilots' views. The attitude of the iPad as a content manager must change to the iPad as a knowledge-sharing source.

The key learning results from this research indicate that:

- Management must understand the intended use of disruptive technology from the pilot's perspective and not from a managerial perspective. The pilots see the iPad as technology to enhance SA while management sees an iPad as a technology to store content.
- Training must be designed for the iPad in flight operations with that intended use in mind. Absent training the pilots did not accept or intend to use the technology.
- Management support from the perspective of use rather than restriction is needed. Pilots must be allowed to experiment with the technology to improve upon use.
- For the iPad to enhance SA for the pilots requires connection to an Internet or data source. Absent connectivity the iPad will carry content rather than fucntion as a knowledge sharing system

For the creative destructive potential of iPads to occur in aviation, and for the Company to realize the benefits and opportunities presented with creative destruction, there must be an understanding first of the "job" the pilots or users of a technology intend to accomplish. At the company, the managers and pilots did not share the same view of the "job" that iPads were to fulfill preventing creative destruction and disruptive innovation. If the technology was managed with that "job" in mind, proper training would have integrated the iPad into situational use and resulted in technology acceptance. This training might have linked the "job" to a positive impact on the Company's efficiency and productivity. Once the "job" is viewed as knowledge sharing rather than content storage the opportunities of creative destruction and disruptive innovation will be realized. The use of the technology will improve the level of resource management in the cockpit and create better SA from knowledge sharing that will result from proper technology management. Recognition of the ‘job” will design proper training resulting in acceptance, use and productivity as Christensen and Kirkpatrick predict.

Future Research Considerations

The exploratory research identified the pivotal role to use and improvements the “job” the technology is supposed to fulfill in the limited case of iPads in airline cockpit, and how differences between intended users and those procuring the technology can then create issues with training, acceptance and use. As Christensen et al. (2011) notes the “job” the user or customer discovers is rarely the intended use the manager or trainer has in mind when the technology has a disruptive potential.

Possible future research could take the idea of the “job” and use that as the first step in a technology implementation model development. As the literature and the exploratory study show, the “job” identifies use, use leads to required training, training leads to acceptance and acceptance leads to benefits for the organization. Research may seek to develop a technology implementation plan based on beginning with an understanding of the “job.” The potential for this research may result in contribution to a model of predictive creative destruction and disruptive innovation.

Future research may take the “job” concept into inclusion in the string of TAM studies since Davis (1986). The current models begin with the technology as an accepted fact. Future acceptance of technology models might include a quantitative assessment of the accuracy of the intended “job” from the user and customer perspective. Future research could also take the same organization and scenario of technology as iPads in the cockpit and execute a full quantitative study using one of the TAM such as Davis' (1986) TAM or Venkatesh's (2000) UTAUT.

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APPENDIX A

SURVEY INSTRUMENT

Using the UTAUT model from Venkatesh et al. (2003) as a model for questions given that UTAUT is designed to measure social influence, perceptions as to use and usability as well as self-efficacy...Each question will have a Likert scale of 1 (Strongly Disagree) through 5 (Strongly Agree). The surveys will be sent to those with experience using iPads in simulators or flight operations found on pilot sites.

Descriptive Statistics as to Performance Expectancy

1. I find iPads easy to use in flight operations.
2. Using iPads I can accomplish tasks for flight operations more quickly than paper charts and manuals.
3. Using the iPad increase my productivity in flight.
4. Using iPads hinders Crew Resource Management
5. Using iPads negatively impacts Situational Awareness

Descriptive Statistics for Effort Expectancy

6. My interaction with the iPad is clear and understandable while engaged in flight operations.
7. The training I received for the iPad was sufficient for me to do my job.
8. The iPad is easy to use.
9. Learning to use the iPad is easy for me so the training was not necessary.

Descriptive Statistics for Attitude Toward Using

10. Using the iPad to replace paper manuals and charts is a good idea.
11. The use of iPads in flight makes operations more enjoyable.

Descriptive Statistics for Social Influence

12. The union I belong to has been supportive of integration of iPads into flight operations.
13. The airline management has been supportive of integration of iPads into flight operations.
14. My colleagues have been supportive of integration of iPads into flight operations.
15. The airline's training department has been supportive of integration of iPads into flight operations.

Descriptive Statistics for Facilitating Conditions

16. I have the knowledge necessary to employ the iPad efficiently in flight operations.
17. The company provides necessary support to use the iPad.

Descriptive Statistics for Self-Efficacy

18. I can complete most tasks needed for employment of iPads if there was no one around to tell me what to do.

Descriptive Statistics for Behavioral Intention

19. I intend to use the iPad in flight operations as often as possible.
20. I intend to explore additional applications for the iPad in flight operations.

In a short answer, what additional applications could you see the iPad using to increase operational efficiencies?

Would you be willing to participate in an interview to provide more insight into iPad use in the cockpit? Yes/No

If Yes, please provide an email at which I may contact you.

Thank you for your time,

Matthew Boyne
Doctoral Candidate
Pepperdine University
United Airlines
ALPA Member #XXXXXX

APPENDIX B

EMAIL TO PROSPECTIVE PARTICIPANTS

Dear Captain X or Doctor Y,

I am a doctoral candidate researching the integration of tablet computers, such as iPads into commercial flight operations. Based on the response to the survey posted on the ALPA website, you provided your email address and noted that you might be interested in participating in an interview study I am conducting for my dissertation in partial fulfillment of my doctorate in education from Pepperdine University.

My study is called: "Disrupting Aviation: An Exploratory Study of the Opportunities and Risks of Tablet Computers in Commercial Flight Operations."

The purpose of this study is to develop an understanding of the role of iPads or other tablet computers play in flight operations, opportunities that may be recognized as to improvements the portable computers may bring, risks to safe flight and potential influence or impact upon Crew Resource Management (CRM) and Situational Awareness (SA).

You are recognized by your colleagues at the Airline Pilots' Association (ALPA) as knowledgeable about CRM and SA given your ATP certification, and have had significant recognized experience in the fields of pilot training or technology implementation in the cockpit. Given your status as a Captain or First Officer at ABC Airline along with your carrying an Airline Transport Professional Rating your professional qualifications are respected by industry and the Federal Aviation Administration.

If you are willing to participate, I would like to interview you by telephone (or in person) for approximately one hour at your earliest convenience. If you are interested in participating, please read the attached informed consent, sign, scan, and email it back to me prior to our interview. If you have any questions about this study, I can be contacted by email XXXXX@pepperdine.edu or by telephone at XXX-XXXX.

Thank you,

Matthew Boyne

APPENDIX C

PARTICIPANT INFORMED CONSENT

I authorize, Matthew Boyne, a doctoral student in education at Pepperdine University, to include me in the research project entitled "Disrupting Aviation: An Exploratory Study of iPads, Opportunities and Risks in Commercial Aviation" This study is being conducted under the supervision of Dr. Jack McManus. I have been asked to participate in this research project, which is designed to explore the opportunities, and risks that the introduction of tablet computers may create within the airline flight environment and the possible impacts of the tablets upon safety awareness developed from CRM and SA.

The study will last approximately 60 minutes and will consist of open-ended interviews conducted by the researcher, who will attempt to identify common patterns and practices from the participants that may contribute to a successful and sustainable nonprofit news outlet online. I have been asked to participate in this study because my professional background meets the following characteristics:

You are recognized by your colleagues at the Airline Pilots' Association (ALPA) as knowledgeable about CRM and SA, or have had significant recognized experience in the fields of pilot training or technology implementation in the cockpit. Given your status as a Captain or First Officer at ABC Airline along with your carrying an Airline Transport Professional Rating your professional qualifications are respected by industry and the Federal Aviation Administration.

The result of this study may have both theoretical and practical significance. For the first time in modern commercial aviation, technology is being introduced into flight operations that was not designed for an aviation purpose, and has the capability to transmit and receive information from outside the standard, formal communication channels. Government aviation human factor scientists within the FAA have not yet researched these capabilities and there are unidentified risks and opportunities given any technological implementation, especially a safety-critical one such as flight. The possibilities that pilots in the cockpit will have greater situational awareness given in-flight Internet connectivity than those in command and control positions, such as air traffic controllers or company managers, create challenges from a system-wide CRM perspective.

I am aware of the following conditions of this study that comply with Pepperdine University policies:

- My participation in the interview is voluntary and I am free to withdraw from participating at any time.
- The interview will be recorded. An audio file of the recordings will be securely stored on a laptop in a locked safe for five years. After that, the files will be erased.
- If I so choose, my identity will be kept confidential. A code will be assigned to identify my organization and another code will be assigned to identify me.

- There are no known risks to the participants.
- The findings of the study will be published in the researcher's dissertation and possibly other scholarly journals.
- No compensation will be provided to me for participation in this study.

The purpose of the research process was explained to me. I am willing to participate in the interview. If I have questions about my rights as a research participant, I may contact Pepperdine University Graduate and Professional Schools Institutional Review Board (GPS IRB) at (310) 568-5753 or at gpsirb@pepperdine.edu.

___I would like my name and organization to be treated with confidentiality
___I waive my right to have my name and organization to be treated with confidentiality

______________________________ Signature Date

The contact information for the researcher and faculty advisor are as follows:

Matthew Boyne
Doctoral Candidate
Pepperdine University
Graduate School of Education and Psychology

Dr. Jack McManus (faculty advisor)
Pepperdine University
Graduate School of Education & Psychology

APPENDIX D

INTERVIEW PROTOCOL

Time and Date of the interview:

Place:

Interviewee:

Open with introductory comments:
1. Thank the participant.
2. Explain the process including recording of the interview.
3. Complete the informed consent.

Questions:

First Theme: Influence on CRM and SA: What role do you envision for tablet computers in flight operations to enhance crew communication, coordination and awareness? RQ 3 and

Second Theme: Education and training: How should training and education be structured to effectively prepare pilots to use tablet computers during flight operations? RQ 1, 2 and 3.

Third Theme: Technology acceptance: How should tablet computers be employed to maximize effectiveness and efficiencies during flight operations? RQ 1-2.

Fourth Theme: Future capabilities: How well do you feel the initial integration of tablet computers was done by the FAA and airlines? RQ 3 and 4.

Fifth Theme: Flight safety: What risk mitigation elements should employed to ensure tablet computers do not compromise a safety culture on the flight deck? RQ 1-4.

Closing:
1. Ask the participant if there is something else that he or she would like to ask.
2. Ask the participant if they would recommend another person or news outlet who might participate in this study. Ask the participant if they would like to be named as a recommender in subsequent correspondence with the nominee.
3. Thank the participant.