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The Manual Flight Skill of Airline Pilots

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THE MANUAL FLIGHT SKILL OF MODERN AIRLINE PILOTS

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ABSTRACT

THE MANUAL FLIGHT SKILL OF MODERN AIRLINE PILOTS

by Antonio F. Puentes

The manual flight ability of commercial airline pilots has been scrutinized after several aviation disasters in the first decade of the 21st century where pilot error has been a contributing cause. Voluntary pilot incident reports from the National Aeronautics and Space Administration's Aviation Safety Reporting System (ASRS) were examined as one method to determine the prevalence of manual flight skill decline among airline pilots. The investigation studied reports from unstabilized approach to landings where the pilots manually controlled the aircraft during descent. An analysis of the ASRS reports from pilots flying traditional flight deck aircraft compared with pilots flying aircraft with advanced technology flight decks revealed no significant difference in unstabilized approaches. Two additional analyses comparing ASRS reports from regional air carriers versus major air carriers as well as international operations and domestic operations from major air carriers, determined no significant differences in unstabilized approaches. The research indicates that ASRS voluntary incident reports cannot determine significant differences in airline pilot manual flight control between different airline operation types or flight deck technologies.

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Introduction

Throughout history, people have looked for ways to reduce workload through the use of tools and machines. In the 19th century, machines began to be used to complete the manual tasks that humans once performed, sparking the industrial revolution. Today, automated systems perform many daily tasks throughout our lives. Alarm clocks wake us up at a specified hour, programmed brewing machines make our coffee, and robots automatically vacuum the floor while maneuvering around obstacles.

In the automotive industry, automation assistance has significant potential for applications in passenger vehicles, heavy trucks, and public transportation (Bishop, 2000). With the help of on-board vehicle automation, cars can now parallel park themselves without the need of a human driver (Moran, 2006). Now that cars can perform this challenging task, what will happen to the parallel parking skill of the driver if the automatic system is no longer available? Research in basic motor skills has shown that the length of delay without practice has a significant effect on the ability to recall and perform a learned task (Savion-Lemieux, & Penhune, 2005). Therefore, the once proficient driver will have a much more difficult time trying to manually park without the automatic system. Along with the benefits of automation come consequences, many of which are yet to be discovered.

As a result of prolonged use of automation, pilots flying complicated airliners may also be unprepared to manually take over controls when automation fails or performs unexpectedly. During a routine flight in 2010, a Boeing 737- Next Generation aircraft began an uncontrolled dive towards the ocean below. The First Officer struggled to comprehend exactly what was happening while paralyzed by fear. The Captain, who had left the flight deck to use the restroom, was frantically trying to get back into the locked flight deck. Once entry was gained, the Captain was able to bring the aircraft under control and return to cruise flight. The First Officer had accidently disengaged the automatic pilot, but fear, panic, and the lack of manual flight practice, prevented him from recovering the airplane from its nose dive. This event is not an over dramatized, made for TV movie, but actually happened on an Air India Express flight, according to the official incident report (Directorate General of Civil Aviation, 2010).

The flying public expects that the two pilots sitting on the flight deck are more than capable of flying the aircraft safety while under manual control. However, recent research has indicated that many pilots are not maintaining the basic flying skills required to manually control an airplane safely (Ebbatson, 2009; Gillen, 2008). United States pilots are not immune to this problem and have been recently chastised by the Federal Aviation Administration (FAA) as well as an executive from a pilot union representing thousands of professional pilots for their lack of hand flying practice (Croft, 2010). The ability of Captain

Chesley Sullenberger to manually fly his crippled aircraft safely into the Hudson is the exception rather than the norm (National Transportation Safety Board [NTSB], 2010). The flight skill that Captain Sullenberger demonstrated that February afternoon may have been the dramatic end to an entire era of aviators. A new generation of pilots is earning its wings while becoming increasingly reliant on technology, and may no longer possess the manual skills to proficiently fly complicated aircraft (Ebbatson, 2009; Gillen, 2008).

The Introduction of Automation

From the onset of powered flight, the need for flight control assistance was immediately recognized as a means to improve safety and reduce pilot workload. Lawrence Sperry is credited with developing the first system to automate piloting control tasks, which he successfully demonstrated in 1914. He later went on to develop and patent the gyroscopic instruments that have become the foundation of modern instrumentation (Scheck, 2006). Thanks to the courage of early aviation pioneers like Wiley Post and Jimmy Doolittle, aircraft automation began to take an ever-increasing role on the flight deck and has provided the basis for the operation of commercial aviation in nearly any type of inclement weather. The autopilot was an important development as it freed up cognitive and physical resources in high workload environments as well as mundane cruise flight. Airlines have also promoted autopilot as a means to reduce fuel costs and help their bottom line (Weiner & Curry 1980; Weiner, 1988). Basic autopilots quickly gave way to more complex and intelligent flight automation systems and became more advanced and dependable, allowing pilots to become more dependent upon their use. As technology advanced into the 21st century, the aviation industry has always kept pace, implementing the newest on-board systems and electronics such as the Electronic Flight Instrumentation System (EFIS) and Flight Management System (FMS).

Aircraft terminology has also adapted to changes in technology. The term "cockpit" comes from the nautical reference for the cramped quarters of a junior officer below the main deck (cockpit, n.d.) and quickly carried over to the limited space available for pilots in early aircraft. Today, the term "flight deck" has become synonymous with today's advanced technology aircraft (flight deck, n.d.). While this term also has nautical roots, its origin is aviation specific; derived from the flying boats of the 1920's where the pilots occupied the entire upper level of the aircraft (Johnson, 2009).

Automation took a giant leap forward in the late 1970's when two nearly simultaneous events took place; the two-man flight crew was introduced and the entrance of the "glass cockpit" (the use of digital displays instead of traditional dials and gauges to display flight information) on the flight deck of the Airbus A310 occurred (Airbus, 2011). The aircraft manufacturer Airbus revolutionized the way pilots interact and interface with their aircraft in fundamental ways. Analog dials gave way to digital displays and traditional cable-and-pulley flight controls became remotely operated, electronically actuated systems known as “fly-by-wire.” In the Airbus A310, computers drive complicated flight management systems, simplifying pilot tasks and freeing up cognitive resources. The first glass cockpit aircraft, the Airbus A310 and the Boeing 767 and 757, were years ahead of the way the previous generation of aircraft were flown and managed. Tasks such as holding patterns, that were normally calculated and drawn on notepads, were now computed by a flight management computer and graphically displayed on a cathode ray tube (CRT) display. The cognitive workload of entering and flying a holding pattern was reduced, freeing up mental resources for other tasks.

Modern technology now available to flight crews has dramatically increased aircraft efficiency and improved safety while reducing workload during critical phases of flight. Unfortunately, the added benefits gained by the use of automation have also created unexpected side effects that could compromise safety. Much effort has been spent on researching the challenges and pitfalls of automating the flight deck and also in the proper way to develop flight deck technology (Billings, 1991; Harris et al, 1985; Weiner & Curry, 1980; Curry, 1985). For all the effort spent on reducing pilot workload, the actual assistance to pilots during high stress phases of flight is questionable (Billings, 1991).   The lack of recent manual flight practice with modern airline flight crews has the potential to place the entire aircraft in jeopardy. Thousands of hours of flight time without much actual piloting places the proficiency of flight crews into question. Aviation accidents tracked by The Boeing Company (2011) show that 53 percent of all commercial airline fatal accidents since 1959 occurred during the takeoff and landing phases of flight; those segments almost exclusively hand flown by pilots. In a recent survey, 43% of pilots indicated that their manual flying skills have declined since flying advanced technology aircraft (Bureau of Air Safety Investigation, 1998). This decreasing trend in skill required to manually fly the aircraft may signal an unintended consequence of implementing new technology.

Ushering the Era of Complacency

As the technology on the flight deck began to change, capturing the attitudes of pilots who were going through the flight deck revolution revealed crucial insight into the initial acceptance of pilots flying modern aircraft. Many of the transitioning pilots were quick to realize the potential benefits the new automation provided but were immediately aware of the potential for a degradation of manual flying skill and the potential to compromise safety (Curry, 1985; Rudisill, 1995). Researchers have identified that when automation changes the way human operators perform the tasks, complacency begins to manifest itself, especially in multi-task environments such as the flight deck (Parasuraman, Molloy & Singh, 1993). Airline pilot flight instructors noticed that First Officers of automated aircraft who were transitioning to the Captain position in older jet aircraft needed significantly more training time to qualify after "displaying inactivity and complacency" (Weiner & Curry, 1980, p. 9).

Flight deck control systems, such as autopilot and autothrottles, perform many of the physical manipulations of the flight controls most of the older generation of pilots learned from experience. Basic flying knowledge, such as the relationship between specific power settings and pitch attitude, which results in an exact airspeed, becomes more difficult to recall, or is never learned by student pilots when an aircraft performs tasks automatically. The problems associated with complacency from overuse of automated systems can be alleviated to some extent by routine manual flight practice. Many pilots recognize the need to practice "hand flying" during short periods of flight, especially during complex operations such as landing and takeoff, and in and out of congested airports, to overcome the complacency of automation (Weiner, 1985; Curry, 1985). However, the automation was designed to reduce pilot workload during the takeoff and landing phases of flight. Most airlines strongly encourage autopilot use during the majority of operations, but do acknowledge the need for manual practice occasionally as noted by at least one Flight Operation Manual at a United States air carrier (Gillen, 2008). In practice, there does not seem to be any standardization of when to manually fly the aircraft, and each pilot makes that decision based on their own personal comfort level in accordance with company policy and upon agreement of the crew.

Many procedures in and out of heavily congested airports require the sole use of automation as a means of maintaining precise flight tracks in increasing traffic density environments. Many pilots have become accustomed to rely upon the autopilot and automation as standard operating practice. Many times when there is an anomaly or an unexpected automation action, flight crews will try to "program their way out" (Curry, 1985, p. 30) of the situation rather than disconnect the automation and manually fly the aircraft. When a runway assignment on approach to landing is suddenly changed, both pilots may be focusing on the associated piece of technology with their heads down, sacrificing vigilance out the windows. This situation in many cases happens during a critical phase of flight, normally approach to landing, where the airspace becomes congested with arrivals and departures (Damos, John, & Lyall, 1999). In responding to the automation, the human is taken out of the loop of first flying the airplane, and redirects attention and cognitive resources to the automation. The accident of Eastern Air Flight 401 serves as a reminder of what can happen when a flight crew diverts their attention to tasks other than flying the aircraft. An item as trivial as a burned out light bulb on a critical system (landing gear position indicator) at a critical phase of flight (circling the airport) was such a powerful distraction that the flight crew failed to realize the autopilot was not holding their assigned altitude of 2,000 feet and the aircraft crashed into the swampy Florida Everglades (NTSB, 1973).

The over-reliance on automation may also cause pilots to become physically disconnected from the aircraft, and they may miss the subtle aerodynamic warnings of an impending flight hazard. As the aerodynamic loads placed upon an aircraft exceed the ability of the automation to manage the situation, the autopilot suddenly disengages leaving the flight crew with very little time to recover an aircraft that is out of control. The fatal accident of American Eagle Flight 4184 (NTSB, 1996) and near fatal incident of China Airlines Flight 006 (NTSB, 1985) occurred when the autopilot was engaged during a time when the aircraft was struggling to maintain stable flight. The crew did not realize the danger because they were physically disconnected from the aircraft and could not recognize the warnings because the autopilot was operating.

With the autopilot engaged, China Airlines Flight 006 had an engine failure during cruise, causing a change in flight characteristics. Once the autopilot could no longer compensate for the change in flight characteristics, it rolled and plunged 32,000 feet before the pilots recovered, just above the ocean. There were only two injured passengers as a result of the loss of control. Although the aircraft sustained some damage due to the aerodynamic forces experienced from the event, the aircraft was able to make a safe emergency landing approximately 300 nautical miles from the intended destination.

The passengers aboard American Eagle Flight 4184 were not so fortunate. As the aircraft was circling outside of Chicago, significant amounts of ice began to accumulate on the aircraft, which increased the aircraft's weight and altered the aerodynamic characteristics of the wings. Unknown to the flight crew, the autopilot was struggling to maintain the selected altitude while also attempting to handle the change in aircraft aerodynamics. Suddenly, the automation disengaged just as the aircraft rolled inverted and spun uncontrollably towards the ground.

Investigators can only speculate if the pilots were hand flying the aircraft, could they have recognized the imminent danger they were in, and would they have been able to take steps to recover in time. By being physically disconnected from the aircraft, precious moments may be lost during an emergency because the aerodynamic warning signals of danger are lost.

Flight Skill Decay with Non-practice

Early research examining the loss or decay of pilot flight skills used crude flight simulators, or suspended aircraft models. This initial research focused on assessing the recall ability of previously trained skills after a time of disuse, and found that proficiency declines after a period of non-practice (Ammons, Farr, Bloch, Neumann, Dey, Marion, & Ammons, 1958; Fleishman & Parker, 1962; Wright, 1973). Ammons et al. (1958) found that the decay of flight skills was present regardless of the duration of elapsed time without practice. Participants were given up to eight hours of training to proficiency for a simulated flight task. After a "no-practice interval" from 24 hours to two years, a greater loss of skill occurred as time since the last practice increased. Flight skill quickly returned to proficiency, up to 75 percent, in as little as five minutes of practice after the hiatus. Certified pilots also suffered from "profound…rapid… and pervasive" (Childs, Spears, & Prophet, 1983, p. 30) flight skill loss after relatively short periods of non-practice. Private pilots who did not continuously practice flight maneuvers, especially those critical during aircraft emergencies, would quickly lose proficiency in the procedure or the application of those maneuvers in as little as eight months.

In the case of Colgan Air Flight 3407, when the Captain recognized the aircraft was in an aerodynamic stall, he incorrectly applied the required technique for recovery, exacerbating the condition, and rendered the aircraft unrecoverable (NTSB, 2010). Investigators were unable to determine why a certified Captain would act inappropriately to a flight maneuver that is evaluated during initial and recurrent training. Typically, Captains are required to successfully demonstrate these maneuvers every six months while First Officers receive this training once a year. The training is intended to maintain the proficiency of flight crews in identifying and reacting appropriately to in-flight emergencies.

The flying environment today has changed to that of less manual flying and more use of automation. Furthermore, the type of operation also dictates the amount of practice a pilot receives. The shorter trips flown by domestic carriers offer both pilots a daily opportunity to practice their skills. However, that is in sharp contrast to international pilots who may only get a chance to operate the controls a few times per year. Relief pilots during international flights rotate positions to allow the Captain and First Officer an opportunity to rest during cruise flight and normally do not get an opportunity to actually manipulate the controls. The lack of actual flying experience from international flight crews may have contributed to a Sydney bound United Airlines flight that came within 100 feet of a mountain after takeoff from San Francisco in 1999 (Carley, 1999). After experiencing an engine failure, the flying pilot of the B-747-400 did not perform the proper recovery technique, which exacerbated the critical condition of the aircraft and nearly collided with a mountain. The one takeoff and landing the pilot had performed the week before the incident was the first in nearly a year.

Cognitive Aspects of Flight

Flight does not exclusively involve motor skill but is also highly dependent upon cognitive processing, which is just as susceptible to decay after periods of disuse (Childs & Spears, 1986; Arthur et al., 1998; Wright, 1973). Flying is a psychomotor process, involving both motor skills and cognitive processing to achieve the desired flight path and maintain adequate situational awareness. Childs and Spears (1986) found that the majority of flying skill was attributed to cognitive performance and proficiency. Wright (1973) found that flight by reference to instruments, placed significant cognitive demands on pilot participants, and revealed that this type of flying was most affected after non-practice intervals. Recent research has also revealed that cognitive skills, in addition to physical skills, decrease over time without proper practice, especially those skills that were learned early in training but not used for extended periods (Arthur, Bennet, Stanush, & McNelly, 1998).

Cognitive processing is a crucial skill involved in nearly every aspect of piloting. Visual and other sensory cues, combined with flight data, all must be efficiently processed for the pilot to make adequate and appropriate inputs to control the aircraft as desired. For example, small corrections are made to the flight controls, based on information from the flight instruments, to track a desired course or maintain a specified altitude. Baron (1988) described the sensing of flight data, its interpretation and processing, and subsequent physical adjustments of the flight control to achieve the desired flight outcome, as being a “closed-loop” control task. Pilots who are manually flying are continuously performing this closed-loop processing. This skill is fundamental in the accurate monitoring of an aircraft’s progress along a route of flight. Closed-loop processing is the most demanding cognitive process performed on the flight deck because so much information must be understood and acted upon in a very short period of time.

Ebbatson (2009) found that pilots who had significant experience flying traditional, non-glass cockpit aircraft, developed robust mental models of performance characteristics during different phases of flight. These heuristics allowed experienced pilots to quickly and accurately predict and anticipate exactly how the aircraft would perform, thus reducing the high processing demands imposed by closed-loop processing. These pilots developed their own schema for the operation of the aircraft based upon experience with power settings, descent profiles, and rules of thumb. They no longer had to perform complex mathematical calculations to determine when to begin a descent; rather they could simply apply the heuristic model for that situation. Less experienced pilots, lack these heuristics and quickly become saturated, resulting in poor aircraft control and planning. Over-dependence on automated systems exacerbates this issue and further inhibits the ability to develop the required mental models for manual flight.

Ebbatson (2009) conducted research on manual flight skill of pilots transitioning from light twin engine training aircraft to modern airliners. By testing their performance both before and after a 40-hour jet transition course, the differences in control strategies became apparent. The students did not have the proper experience to develop the schema needed to understand how the aircraft would react to different power and pitch settings. The result was large, coarse control inputs to achieve a desired aircraft condition. The students also had significant difficulty in managing the inertia and energy of the larger aircraft, and therefore had more trouble in predicting where in space the aircraft would arrive at a given period of time. When measured after the 40-hour training course, student performance improved most notably in their ability to anticipate the performance of the jet aircraft and make smooth and precise control inputs for the desired outcome.

A New Generation of Pilots

Today, an entire generation of pilots that has flown nothing but advanced technology aircraft make up the majority of the workforce. Recent surveys indicate that 46% of airline pilots had two or less years flying aircraft other than those with glass cockpit (Gillen, 2008). The current generation of pilots is able to command aircraft with increasing levels of sophistication, but is also losing some of the original, “stick-and-rudder” (i.e., manual flight operation) skills. New pilots lack the mental models and schema that older pilots have developed and perfected over decades of flying due to the way pilots interact with modern flight decks (Ebbatson, 2009). It is the concern of many pilots that the current generation of pilots is being trained to be “…‘an era of button pushers’ not pilots” (Rudisill, 1995, p. 4).

The overuse of automation is not entirely the fault of the pilot. The airlines and even regulating authorities must shoulder some of the blame as well through the implementation of various policies and procedures. The airlines promote the use of automation, due to the high level of precision that automated systems afford, as a means of flying efficiently and saving money (Weiner, 1998). In the United States, the FAA has also taken advantage of the capabilities of modern aircraft to increase air capacity in the NextGen air traffic environment (FAA, 2011). Technology no longer attempts to keep pace with the operators who use it, but is becoming a means to save costs and increase the volume of aircraft managed in the same amount of airspace. The result is a pilot population who only knows flying with assistance of automation and feels less and less comfortable with their manual flying ability (Gillen, 2008).

Recent Research on Manual Flight Skills in Airline Pilots

Research conducted by both Ebbatson (2009) and Gillen (2008) focused on the manual flying ability of current airline pilots flying highly automated aircraft. Both used sophisticated, high fidelity flight simulators with pilots performing standardized manual procedures that were evaluated by certified check airman (highly experienced pilots certified by regulating authorities to evaluate pilot training.) The two studies differed slightly in their grading criteria due to different certification standards of the regulating agencies (FAA, and Civil Aeronautics Authority [CAA]).

Gillen (2008) performed flight maneuver testing in a simulator, but used only check airman grades that were consistent with the standards issued by the FAA to measure pilot performance. Grades were issued based on a 1 – 5 scale, in which a score of 5 represented excellent performance and 1 signified major deviations resulting in a crash or loss of aircraft control. A score of 4 represented performance at the highest level of aircraft pilot certification or Airline Transport Pilot (ATP) level and a score of 3 represented basic instrument certification skill level. Captains are required to have ATP certification to serve as pilot in command for airline-operated flights. Gillen found that most of the airline pilot participants performed below ATP standards and closer to basic instrument skill level for those maneuvers tested even though they were all highly experienced pilots with major airlines. The U.S. Department of Transportation (DOT) defines a major air carrier as having total annual operating revenue of greater than U.S.$1billion (U. S. Department of Transportation [DOT], 2011). There was no correlation between total number of flight hours and the performance of the pilots. All pilots were current airline pilots for a major United States air carrier and proficient in their assigned aircraft.

Ebbatson (2009) used similar check airman grading for the flight maneuvers examined, but also collected flight simulator data to further analyze the level of performance. The grading was used as a validation for the results of the simulator data. Ebbatson measured manual flight performance from 66 current airline pilots immediately after their annual proficiency check with the airline and without any specific training for the research evaluation. The pilots performed typical flight maneuvers normally demonstrated during their annual proficiency check, consisting of an Instrument Landing System (ILS) approach to landing and a missed-approach or “go-around”. The pilots also completed a demographic survey, which outlined their previous flight history and recent manual flight practice. Ebbatson’s findings showed that airline pilot manual flight skill was very near to the minimum acceptable range for basic instrument flight competency, as graded by the check airmen. In addition, airspeed control was especially vulnerable to flight skill decay regardless of pilot total flight hours and operational experience (military, cargo, or airline) the pilots had received prior to their current assignment. The ability to correlate this information with flight simulator data gave insight into specific flight realms in which flight performance was especially waning, primarily the ILS approach to landing phase. Ebbatson's research revealed that the amount of manual flight practice a pilot performed in the weeks immediately prior to the test, and during the course of normal airline operations, was directly associated with the level of flight skill decay observed across all pilots evaluated during the course of the study. The lack of recent manual flight experience was correlated with poor measured performance. The overall finding was that manual flight performance of pilots flying highly automated aircraft suffered degradation regardless of previous aircraft types flown or the type of operational experience accumulated throughout the career of the pilot.

Using Pilot Voluntary Incident Reports

Evaluation of flight crew performance during flight operations can be very valuable for the researcher. However, acquiring real world safety data utilizing a Line Orientated Safety Audit (LOSA) can be a challenge due to enhanced airline security measures that have been implemented since September 11, 2001. Gaining access to the flight deck during flight to conduct research is nearly impossible due to current security concerns, severely restricting how observational data can be obtained. Furthermore, observational research on the flight deck is not efficient because the opportunity to observe low-frequency incidents that would require manual intervention is extremely limited. One solution that provides a similar glimpse into the operational environment is voluntary incident reports that may be obtained from National Aeronautics and Space Administration (NASA) Aviation Safety Reporting System (ASRS) incident reports.

The value of voluntary incident reports is immense, and the safety benefits have been proven across many industries beyond aviation (Billings, 1998; Chappell, 1994). Voluntary incident reports come from pilots experiencing real events and can provide insight into real-world operations that cannot be achieved in a laboratory setting. Researching incidents versus accidents provides access to a higher volume of reports without the need for qualitative investigation of a few accidents. Most important, the narrative format of incident reports provides the necessary sequence of events to build a complete picture of the factors leading to an incident and can often help to prevent future events (Billings, 1998).

Voluntary incident reports are fallible as well. The motivation to provide details of a near accident is not always the same for each reporter, and therefore a pilot may not complete a report for every incident (Chappell, 1994; Johnson, 2003). The motivation for reporting an incident may be from the potential immunity from regulating agencies for certain types of incidents, or perhaps just the prospect of contributing to aviation safety. Every reporter provides a bias when providing a voluntary incident report based upon his or her motivation to do so. In personal narratives, details may be omitted or embellished based upon the significance of certain details or sequence of events (Chappell, 1994). These biases are present in every report and must be recognized when drawing conclusions based on the reports.

The Aviation Safety Reporting System

The Aviation Safety Reporting System at NASA Ames Research Center was begun in 1979 and to date has amassed a database of over 900,000 voluntary reports have been amassed. NASA administers ASRS at the request of the FAA. Pilots, controllers, mechanics, and flight attendants all contribute information regarding unsafe events with immunity from punitive action from the FAA (1997). ASRS maintains a high level of respect and credibility from all stakeholders throughout the industry due to the high level of confidentiality maintained.

In 2010, ASRS received over 58,000 reports, of which only 5,500 were fully analyzed and made available to the public. The “full-form” report contains the report narrative as well as 15 pages of additional coded information by expert analysts based upon the original report that can be used for data retrieval and statistical analysis (see Appendix A for a sample of the coding form). A database containing all “full-form” reports is maintained by ASRS and can be accessed by the public via an Internet-based interface (see Figure 1). The Internet interface allows searches of the entire database, retrieving only those reports that match the search criteria.

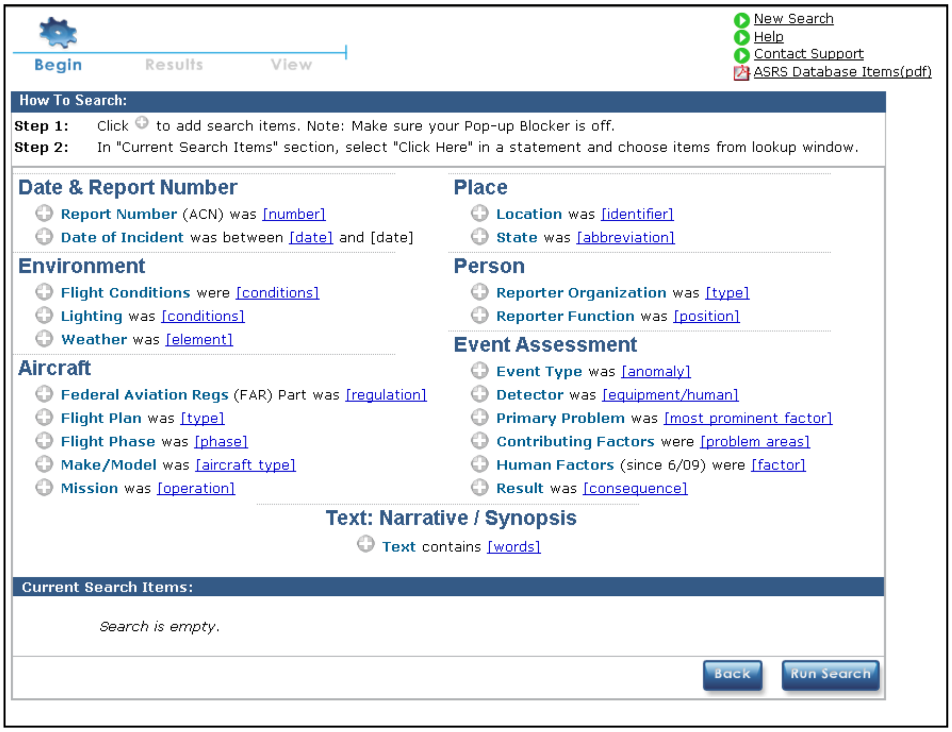

Figure 1. ASRS Internet search interface

ASRS has produced over 60 research studies, and the database records have been used by countless other researchers since its inception. The information retained from the ASRS provides a unique opportunity to draw events from the past that would normally not be available to researchers. Therefore, it would be possible to select reports from the past that can be evaluated and compared to current-day reports in order to draw conclusions about differences between two periods of time. Identifying instances of manual flight deviations during the time that advanced technology aircraft were first introduced as compared to those instances occurring when advanced technology aircraft were almost exclusively operated provide valuable insight into the nature of the current issue of manual flight skill decay. Many of the issues unique to advanced technology aircraft such as complacency, over-reliance on automation, and lack of hand-flying experience could be recognized by such a comparison.

According to the NTSB, there were only two fatal airline accidents in the United States between the years 2006 and 2011. Both accidents involved regional or commuter airlines (annual total operating revenues of under $100 million) and pilot error as a primary cause (DOT, 2011; NTSB, 2007; NTSB, 2010). As a direct result of these accidents, regional airline pilot training and total flight experience was the subject of debate and scrutiny by the U.S. Congress and the FAA. U.S. Representative Jerry Costello introduced the Airline Safety and Pilot Training Improvement Act H.R. 3371 (2009) mandating an increase in total flight experience for new regional First Officers from 250 to 1,500 total flight hours. Although the bill passed the House of Representatives but stalled in the Senate, the idea remains popular and may be re-introduced. New information regarding the manual flight ability of the current generation of pilots can significantly influence future training procedures and regulations.

Total flight experience is not always an adequate marker or indicator of manual flight performance. As mentioned earlier, Pilots who fly international routes (i.e., international pilots) have significantly fewer opportunities to perform takeoff and landings compared to their domestic operating counterparts. Given the limited practice of manually flying aircraft, international pilots are more prone to experiencing flight deviations than pilots who routinely perform these tasks. Although required to perform a minimum number of takeoff and landings, there is no requirement that takeoff and landings be performed in an actual aircraft. Flight simulators are used to maintain the currency of pilot skill when they are unable to perform the necessary maneuvers with the aircraft. The limited practice obtained by international pilots in actual aircraft may place the aircraft, crew, and passengers in jeopardy when conducting flight operations, and there are no foreseeable changes to these requirements.

Research Objective

Evidence supports a decline in manual flight skill of pilots who fly highly automated modern aircraft. Research conducted thus far has provided valuable insight into quantifiable performance issues captured using high fidelity simulators and trained professionals. However, the majority of these studies have been conducted in controlled environments that only mimic the actual environment. Gathering data on pilot manual flight skills while operating actual flight schedules is the most sought after piece of the puzzle and also the most challenging. The purpose of this thesis was to evaluate research conducted on manual flight skill loss by identifying instances when manual flight performance fell below acceptable and safe levels, as recognized by the pilots themselves during actual flight operations. ASRS incident reports were used to answer the following questions in regards to the manual flight skill of airline pilots:

1. Do ASRS incident reports indicate that there are differences in the manual flight performance of airline pilots in traditional flight decks compared to current-day airline pilots using advance flight decks?
2. Do ASRS incident reports indicate that there are differences in the manual flight performance of regional airline pilots compared to major airline pilots?
3. Do ASRS incident reports indicate that there are differences in the manual flight performance of internationally operating airline pilots compared to United States domestically operating pilots?

Methods

Procedure

Exemption status was authorized from the San José State University's Institutional Review Board (see Appendix B) to conduct the present study using voluntary pilot incident reports from NASA's Aviation Safety Reporting System.

Traditional versus advanced flight deck aircraft. Two independent searches were performed using the ASRS Internet database for incident reports identifying events of potential degradation of manual flying ability. The searches each consisted of two-year time periods beginning January 1993 through December 1994, and January 2009 through December 2010. The 1993-1994 reports would be sorted to include only those aircraft with traditional flight deck aircraft, while the 2009-2010 datasets would be sorted to include only advanced technology flight decks aircraft.

Additional database filters were used to limit the search to include only those reports from Section 14 of the Code of Federal Regulation (CFR) Part 121 Certified Air Carriers. In previous studies, several different phases of flight were manually flown in a flight simulator: ILS instrument approach, missed approach, go-around, and holding (Gillen, 2008; Ebbatson, 2009). However, only on rare occasions do pilots typically perform all these maneuvers during scheduled operations. To maintain consistency with previous research and also capture the most representative flight maneuvers, the initial approach, final approach, and landing flight phases were selected as additional filters. These flight phases have resulted in 49% of all commercial jet-powered airline fatal accidents since 1959 (Boeing, 2011).

The resulting datasets were imported in spreadsheet form using .xls format for use with Microsoft Excel®. The datasets contained categorized information across the columns such as location, number of crew, aircraft type, summary, and narrative. The individual reports populated each row. Utilizing the sort feature of Microsoft Excel®, the information could be sorted by individual category as desired.

The 1993-1994 dataset was sorted by aircraft type, which grouped each make and model aircraft together. This method allowed quick visual identification of all advanced technology aircraft (e.g., A320, B-767), which could then be eliminated from the 1993-1994 dataset. The same process was repeated for the 2009-2010 dataset and traditional flight deck (e.g., DC-10, B-727), aircraft were eliminated from the spreadsheet. Any aircraft that could not be identified as an advanced or traditional flight deck aircraft, such as corporate aircraft, or unspecified make and model was eliminated from the dataset.

Each report narrative was analyzed to identify those reports that met the criteria of aircraft typically being manually or “hand” flown during the event.

There are many interpretation of manual flight, therefore for the purpose of this research, manual flight was defined to be:

Pilot manipulation of the flight controls, without the assistance of flight automation, specifically the autopilot and autothrottles; to maintain lateral, vertical, and longitudinal control of an aircraft.

To qualify as being hand flown, the reporter would need to state that the aircraft was under manual control or indicate that the automation was disarmed during the event. The autopilot and autothrottles must not have been engaged. This information could only be obtained by reading the narrative, as the ASRS coding does not provide that information. If the aircraft could not be determined to be under manual flight control, the report was discarded.

In addition to being hand flown, there must have also been a departure from standard operating protocol or flight profile that demonstrated an unsafe act or procedure. A stabilized approach as defined by the Flight Safety Foundation's Approach and Landing Accident Reduction (ALAR) Task Force (2000) was used as a measure of an unsafe flight profile (see Figure 2). If any one of these elements was not satisfied, then the approach was considered unsafe and the report was selected.

Reports that indicated a departure from the stabilized approach criteria that may have been caused by an external force, such as air traffic control (ATC) handling, Traffic Collision and Avoidance System (TCAS) II alerts, or weather conditions were discarded. These external forces introduced potential confounds that made it difficult to determine whether an unstabilized approach was due entirely to the manual flying ability of the pilot.

ATC handling factors included variations in controller guidance that may cause pilots to perform an unstabilized approach in order to comply. Examples include late or incorrect turns onto the final approach course and maximum or minimum speed restrictions. Pilots are required to comply with all TCAS II alerts to avoid potential traffic conflicts. Often the Resolution Advisory that accompanies a traffic alert requires a maximum performance turn, climb, or descent. Often these alerts occur during approach to landing when aircraft are in close proximity to each other. Weather phenomena such as wind shear and microburst, often occur without warning and can quickly cause an unstabilized approach. These types of external forces and events cause the pilots to deviate from their planned approach profile and provide little time to adjust to the changing situation while at low altitudes. In addition, pilots who indicated that their performance was affected by fatigue were also eliminated. The reports that met these final requirements were tallied for statistical analysis.

Recommended Elements Of a Stabilized Approach

All flights must be stabilized by 1,000 feet above airport elevation in instrument meteorological conditions (IMC) and by 500 feet above airport elevation in visual meteorological conditions (VMC). *An approach is stabilized when all of the following criteria are met:*

1. The aircraft is on the correct flight path;
2. Only small changes in heading/pitch are required to maintain the correct flight path;
3. The aircraft speed is not more than V_{REF} + 20 knots indicated airspeed and not less than V_{REF};
4. The aircraft is in the correct landing configuration;
5. Sink rate is no greater than 1,000 feet per minute; if an approach requires a sink rate greater than 1,000 feet per minute, a special briefing should be conducted;
6. Power setting is appropriate for the aircraft configuration and is not below the minimum power for approach as defined by the aircraft operating manual;
7. All briefings and checklists have been conducted;
8. Specific types of approaches are stabilized if they also fulfill the following: instrument landing system (ILS) approaches must be flown within one dot of the glideslope and localizer; a Category II or Category III ILS approach must be flown within the expanded localizer band; during a circling approach, wings should be level on final when the aircraft reaches 300 feet above airport elevation; and,
9. Unique approach procedures or abnormal conditions requiring a deviation from the above elements of a stabilized approach require a special briefing.

An approach that becomes unstabilized below 1,000 feet above airport elevation in IMC or below 500 feet above airport elevation in VMC requires an immediate go-around.

Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force (V1.1 November 2000)

Figure 2. Recommended elements of a stabilized approach from Flight Safety Foundation. Reprinted with permission from Flight Safety Foundation. Copyright © 2000 by Flight Safety Foundation

Regional air carriers versus major air carriers. A third ASRS database search was performed using the ASRS Internet interface for a 10-year period beginning with January 2001 and ending December 2010. The Internet interface was used to filter results capturing only CFR Part 121 Air Carriers during the approach and landing phases. Unlike the previous database searches, one additional search filter was used. From the Event Type search item, the In-flight Event category was chosen, followed by the value Unstabilized Approach. This additional step produced only those reports that an ASRS Analyst coded as unstabilized. The purpose for this additional step was to limit the total number of reports to fewer than 5,000, which is the maximum results allowed.

The resulting dataset was then sorted by aircraft type using Microsoft Excel® into two categories, separating the regional aircraft (e.g., EMB-145, ATR-72) from those used by major air carriers (e.g., B-737, A320).

The report narratives were analyzed to identify those reports that met the criteria of typically being manually or “hand” flown during the event. In addition to being hand flown, there must have also been a departure from standard operating protocol or flight profile that demonstrated an unsafe act or procedure. If any one of the elements in the Flight Safety Foundation ALAR Task Force’s stabilized approach criteria was not satisfied then the approach was considered unsafe and the report was selected. The reports that met these final requirements were tallied for statistical analysis.

Reports that indicated a departure from the stabilized approach criteria that may have been caused by an external force, such as ATC handling, TCAS II alerts, or weather conditions were discarded. These external forces introduce potential confounds that question whether an unstabilized approach was due entirely to the manual flying ability of the pilot. In addition, pilots who indicated that their performance was affected by fatigue were also eliminated. The reports that met these final requirements were tallied for statistical analysis.

International versus domestic operations. Using the reports previously identified as Major Air Carriers during the same 10-year period, additional sorting was conducted using Microsoft Excel® to separate aircraft associated with international operations. Typically these aircraft are larger, wide-body aircraft such as B-747, A310, and MD-11. Additional sorting was needed to identify those incidents that occurred at foreign airports or the reports that identified an additional relief pilot (check airmen excluded) signifying flights that exceeded eight hours of flight time. Only aircraft that were considered wide-body, operating at a foreign destination or with an additional relief pilot were included.

The report narratives were analyzed to identify those reports that met the criteria of typically being manually or “hand” flown during the event. In addition to being hand flown, there must have also been a departure from standard operating protocol or flight profile that demonstrated an unsafe act or procedure. If any one of the elements in the Flight Safety Foundation APLR Task Force’s stabilized approach criteria was not satisfied then the approach is considered unsafe and the report was selected. The reports that met these final requirements were tallied for statistical analysis.

Reports that indicated a departure from the stabilized approach criteria that may have been caused by an external force, such as ATC handling, TCAS II alerts, or weather conditions were discarded. These external forces introduce potential confounds that question whether an unstabilized approach was due entirely to the manual flying ability of the pilot.

International operations require long duty periods across multiple time zones, and therefore fatigue cannot be avoided. Fatigue was determined to be inevitable factor for international operating pilots and was therefore was not used as a basis for report elimination.

Data Analysis

A Chi-Square (χ^2) analysis was determined to be the appropriate statistic to compare the datasets and determine if there were actual differences in manual flying ability. The χ^2 test measures how observed data in independent samples will compare to the expected or predicted outcome of that data. This test would indicate a real difference in the datasets and not just a difference found by chance or sampling errors. In determining the answer to the research questions listed in the previous section, they were formulated into mathematical questions containing a null and alternative hypothesis.

1. Null Hypothesis (**H_0**): There is no significant difference between the number of unstabilized, manually flown approaches from airline pilots operating traditional flight deck aircraft from current-day airline pilots operating advanced flight decks.

2. Null Hypothesis (**H_0**): There is no significant difference between the number of unstabilized, manually flown approaches of regional airline pilots from those flown by major airline pilots.

3. Null Hypothesis (**H_0**): There is no significant difference between the number of unstabilized, manually flown approaches from internationally operating airline pilots from United States domestically operating airline pilots.

Results

Traditional Versus Advanced Flight Deck Aircraft

The dataset covering the years 1993-1994 yielded a total of 2,455 reports. Of that dataset, 998 reports pertained to aircraft with traditional style flight decks only. Of those, 36 reports indicated degradation in manual flying ability as indicated by a deviation from the stabilized approach criteria.

The dataset covering the years 2009-2010 yielded a total of 1,267 reports. Of that dataset, 930 reports pertained to aircraft with advanced flight decks only. Of those, 30 reports resulted in degradation in manual flying ability as indicated by a deviation from the stabilized approach criteria.

A total of 1,928 ASRS reports were determined suitable for analysis. The breakdown of the report totals is presented in Table 1.

Table 1. ASRS report totals for traditional flight decks and advanced flight decks

	Total Reports	Qualifying Reports	Unstabilized Approaches
Traditional Flight decks	2455	998	36
Advanced Flight Decks	1267	930	30
Total Reports	3722	1928	66

The Chi-Square (χ^2) test was manually computed using a two-step procedure: calculating the expected frequencies and calculating the χ^2 test statistic. The expected value is the hypothetical outcome of the data if the null hypothesis is true, and was determined by first tabulating and then summarizing the data. A 2x2 table was constructed including the marginal totals, from which the expected values could be calculated. Multiplying each of the column marginal totals by each of the row marginal totals in Table 2 and dividing by the total sample size determines the expected frequencies shown in Table 3.

Table 2. Marginal totals for traditional flight decks and advanced flight decks

	Unstabilized	Inconclusive	Total
Traditional Flight Decks	36	962	998
Advanced Flight Decks	30	900	930
Total	66	1862	1928

Table 3. Expected values for unstabilized approaches for traditional flight decks and advanced flight decks

	Unstabilized
Traditional Flight Decks	$E = \frac{66x998}{1928} = 34.16$
Advanced Flight Decks	$E = \frac{66x930}{1928} = 31.84$

$$\chi^2 = \frac{(36 - 34.16)^2}{34.16} + \frac{(30 - 31.64)^2}{31.64}$$

$$\chi^2 = 0.20$$

The table was determined to have one (1) degree of freedom. With the degrees of freedom calculated and the χ^2 value known, this information is compared to a distribution table for critical value of χ^2. A significance level of α= 0.05 was used to provide a 95% confidence level in the event the null hypothesis was rejected.

From the distribution table for critical values of χ^2 with one (1) degree of freedom and a α= 0.05, the critical value is 3.84 (Howell, 1985). The calculated χ^2 value of 0.20 falls well below the critical value of 3.84. The distribution table shows the estimated probability for this χ^2 value to be between 0.75 and 0.5. The confidence level falls well below the 95% required and therefore the null hypothesis was not rejected. Table 4 summarizes the results of the analysis.

Table 4. Summary of traditional and advanced technology flight deck analysis results

Traditional Flight Deck	Advanced Technology Flight Deck
998 Total Reports	930 Total Reports
36 Unstabilized Reports	30 Unstabilized Reports
Expected Value 34.16	Expected Value 31.84
$\chi^2 = 0.20$	
Did not exceed critical value of 3.84	

Regional Versus Major Airline Pilots

The second ASRS database search covering the years between 2001 and 2010 resulted in a total of 667 reports classified as "Unstabilized Approach" by the ASRS analyst. Of that dataset, 129 reports pertained to regional aircraft only. Of those, 17 reports described degradation in manual flying ability as indicated by a deviation from the stabilized approach criteria. Of the 667 reports in the dataset, 455 reports pertained to aircraft flown by major airlines operating domestic only flights. The number of reports that described degradation in manual flying ability as indicated by a deviation from the stabilized approach criteria was 42. The breakdown of the reports is presented in Table 5.

Table 5. Report totals listed by air carrier size

Air Carrier Size	Qualifying Reports	Unstabilized
Regional	129	17
Major	455	42

The Chi-Square (χ^2) test was also manually computed using a two-step procedure: calculating the expected frequencies and calculating the χ^2 test statistic. A 2x2 table was constructed including the marginal totals in Table 6, resulting in the expected frequencies shown in Table 7.

Table 6. Marginal totals for regional air carriers and major air carriers

Air Carrier Size	Unstabilized	Inconclusive	Total
Regional	17	112	129
Major	42	413	455
Total	59	525	584

Table 7. Expected values for unstabilized approaches for regional and major air carriers

	Unstabilized
Regional Air Carriers	$E = \frac{(59x129)}{584} = 13.03$
Major Air Carriers	$E = \frac{(59x455)}{584} = 45.97$

The χ^2 value was calculated following the same procedure as explained in the earlier analysis.

$$\chi^2 = \frac{(17 - 13.03)^2}{13.03} + \frac{(42 - 45.97)^2}{45.97}$$

$$\chi^2 = 1.55$$

With the degrees of freedom calculated and the χ^2 value known, this information is compared to a distribution table for critical value of χ^2. A significance level of α= 0.05 was used to provide a 95% confidence level in the event the null hypothesis is rejected.

From the distribution table for critical values of χ^2 with one (1) degree of freedom and a α= 0.05, the critical value is 3.84 (Howell, 1985). The calculated χ^2 value of 1.55 falls well below the critical value of 3.84. The distribution table shows the estimated probability for this χ^2 value to be between 0.25 and 0.1. The confidence level falls well below the 95% required and therefore the null hypothesis was not rejected. Table 8 summarizes the results of the analysis.

Table 8. Summary of regional and major air carrier analysis results

Regional Air Carriers	Major Air Carriers
129 Total Reports	455 Total Reports
17 Unstabilized Reports	42 Unstabilized Reports
Expected Value 13.03	Expected Value 45.97
$\chi^2 = 1.55$	
Did not exceed critical value of 3.84	

International Versus Domestic Airline Pilots

The second ASRS database search covering the years between 2001 and 2010 resulted in a total of 667 reports classified as “Unstabilized Approach” by the ASRS analyst. Eighty-three reports pertained to internationally operating aircraft only. Of those, 12 reports resulted in degradation in manual flying ability as indicated by a deviation from the stabilized approach criteria. From the same 667 reports in the dataset, 455 reports pertained to aircraft flown by major airlines operating domestically in the United States only. The number of reports that described degradation in manual flying ability as indicated by a deviation from the stabilized approach criteria was 42. The breakdown of the reports is presented in Table 9.

Table 9. Report totals listed by operation type

Operation Type	Qualifying Reports	Unstabilized
International	83	12
Domestic	455	42

The Chi-Square (χ^2) test was also manually computed using a two-step procedure: calculating the expected frequencies and calculating the χ^2 test statistic. A 2x2 table was constructed including the marginal totals in Table 10, resulting in the expected frequencies shown in Table 11.

Table 10. Marginal totals for international and United States domestic operations

Operation Type	Unstabilized	Inconclusive	Total
International	12	71	83
Domestic	42	413	455
Total	54	484	538

Table 11. Expected values for unstabilized approaches for international and United States domestic operations

	Unstabilized
International Operations	$E = \frac{(54x83)}{538} = 8.33$
U.S. Domestic Operations	$E = \frac{(54x455)}{538} = 45.67$

The χ^2 value was calculated following the same procedure as explained in earlier analyses.

$$\chi^2 = \frac{(12-8.33)^2}{8.33} + \frac{(42-45.67)^2}{45.67}$$

$$\chi^2 = 1.91$$

With the degrees of freedom calculated and the χ^2 value known, this information is compared to a distribution table for critical value of χ^2. A significance level of α= 0.05 was used to provide a 95% confidence level in the event the null hypothesis is rejected.

From the distribution table for critical values of χ^2 with one (1) degree of freedom and a α= 0.05, the critical value is 3.84 (Howell, 1985). The calculated χ^2 value of 1.91 falls well below the critical value of 3.84. The distribution table shows the estimated probability for this χ^2 value to be between 0.25 and 0.1 meaning the differences were not statistically significant. The confidence level falls well below the 95% required and therefore the null hypothesis was not rejected. Table 12 summarizes the results of the analysis.

Table 12. Summary of international and United States domestic operations analysis results

International Operations	U.S. Domestic Operations
83 Total Reports	455 Total Reports
12 Unstabilized Reports	42 Unstabilized Reports
Expected Value 8.33	Expected Value 45.67
$\chi^2 = 1.91$	
Did not exceed critical value of 3.84	

Discussion

The intent of this thesis was to explore the measurable difference in manual flying performance of airline pilots as indicated by voluntary pilot incident reports. ASRS reports were used in an effort to provide categorical data to support previous research on this topic indicating a decline in manual flight performance due to the prevalence of flight deck automation in modern aircraft.

Traditional flight decks versus advanced flight decks. The analysis showed that there was no significant difference between ASRS reports from traditional flight deck versus advanced flight deck configurations. This does not disprove that there is no real difference, but rather no difference as indicated by the reporters from ASRS incident reports.

The number of qualifying reports for both the traditional and advanced flight decks (over 900 each) was sufficient to produce a statistically significant result. However, the numbers of manually-flown, unstabilized approach reports were only 3.6% and 3.2% of the total respectively. The low number of unstabilized reports was the product of eliminating potential confounds in the data in order to maintain the strict criteria of determining whether the aircraft was manually or hand-flown. Items that could affect pilot performance such as wind gusts, fatigue, or ATC handling would disqualify the use of the report. The results of the statistical testing cannot rule out chance as a conclusion for the two datasets containing nearly identical unstabilized, manually flown approaches to landing.

In the course of reviewing and analyzing the datasets, interesting trends emerged. One of the issues that plagued pilots of traditional aircraft was attempting an approach to landing while aligned with the wrong runway, or even worse, the wrong airport. There were at least 64 of these pilot navigation errors in a dataset of 998 total reports. Newer aircraft with advanced technology flight decks appears to have greatly enhanced pilot situational awareness in this instance, as there were only nine reports of runway confusion out of a dataset of 930 reports.

The report analyses also revealed a substantial increase in unstabilized approaches from pilots using advanced technology flight decks. In 35 incidents, flight crews flying highly automated aircraft often experienced automation surprise when flight automation did not react as intended due to autopilot modes suddenly changing or the pilots mistakenly selected the incorrect mode.

> Flight to ZZZ planned landing for Runway XXL back course. The Captain was the flying pilot and I was pilot monitoring until I was given the flight controls for the company procedures approach. We were given a 30 degree intercept and were cleared for the approach at about a 12 mile final. The Captain inadvertently selected VOR/LOC, which caused the plane to quickly turn the incorrect way heading southwest. The Captain disconnected the autopilot and turned the aircraft back to the northeast to re-intercept the course…We need to be more aware of selection on the MCP and maintain situational awareness at all times. The FOM clearly states that HDG SELECT must be used and we failed to catch this error. When executing a non-precision or back course procedure we must

> maintain situational awareness at all times and listen to our approach briefings very intently. (ACN 834074)

The research did reveal some interesting observations regarding generational differences in their approach to flying aircraft. Reports from pilots in the earlier dataset seemed accustomed to air traffic controllers providing clearances that would stress the aircraft and the pilots flying them to the maximum achievable performance in order to successfully complete the flight. Today, pilots are often critical of air traffic control and blame air traffic controllers for “slam dunk” approaches that resulted in unstabilized approach criteria.

> I am writing this report because after landing in DTW I was instructed by DTW Ground Control to phone the DTW TRACON. I spoke to a Supervisor during our phone conversation he told me he was going to file an airspeed deviation on us because when we were told by his final Controller to maintain 180K until 5-mile final…It was then I called visual on the runway. The Controller then told us we were cleared for the visual for Runway 22R and to maintain 180 KTS until 5-mile final. I immediately told him we were unable to maintain the 180K clearance. At that point the Controller canceled our clearance and vectored back around for an uneventful approach and landing to 22R. During the time we were picking up the runway, we knew we were high on glideslope and our only chance for a stabilized approach was to slow down and to configure the aircraft with Flaps 40. We were also discussing the probability of a go-around. This is without a doubt one of the worst vectors to final in my 35+ years of flying. It was very obvious that the Controller did not have a good understanding of what it takes to descend a B737NG aircraft from an 8000 FT downwind, nor did he understand the dynamics of slowing and descending at the same time. (ACN 844756)

The aircraft flown today are also managed differently, utilizing flight management computers to plot their course and follow specific decent profiles.

The assistance gained by the flight automation can significantly enhance pilot situational awareness and free cognitive resources during the approach to landing. On the other hand, in the case of a last minute runway change or unexpected flight guidance mode, the pilots would become so distracted reprogramming and/or re-arming the automation, that they forget their primary goal of flying the aircraft.

The use of automation is often perplexing to many pilots who were only accustomed to flying in aircraft with traditional style flight decks. This lack of familiarity with technology in the flight deck can be overwhelming. The following excerpt elaborates on this concept.

> This was an extremely challenging approach due to weather, ATC and my lack of experience on a 757 with a glass cockpit modification. I am not type rated in any aircraft with the glass presentation and have minimal experience with glass, especially the speed and altitude tape presentation. This significant change was implemented with an Operating Manual revision and limited instruction several months ago at a recurrent training. I have requested additional training numerous times; however, Management had repeatedly denied my request. … The reality is most pilots do not need the training because they have been trained and flown the B737, B777, Regional Jet or any one of the numerous current day military aircraft. The fact is, I have not been trained on any of these aircraft … I will not fly another one of these modified aircraft until I am comfortable with the new technology. (ACN 884407)

An entirely new generation of pilots seem very comfortable, almost dependent upon technology, often to the point where manually flying an aircraft seems like a foreign concept.

> On approach … with my First Officer flying, the autopilot disconnected by itself about 1,200 FT AGL ... First Officer just looked at me and said what do I do now? I noticed that his FD LOC bar had also disappeared. I told him to fly the airplane using the raw data information that was still displayed with a good ID. He said 'what, down to minimums?' By this time he had gotten high on the GS and I helped him get re-stabilized on the GS and LOC. .... Make the First Officers shoot ILS approaches in training without autopilot, autothrottles and FD to help support basic airmanship skills. Callback conversation with Reporter revealed the following information: The reporter stated that the First Officer had been with the company for two years and prior to that had flown commuter aircraft for a number of years. The Captain believed the First Officer's initial reaction was to go around and try for another coupled approach rather than to fly raw data that was available. They talked about this event on the ground as an educational exercise for both pilots and decided that pilots should be taking responsibility for remaining current flying glass cockpit aircraft in their most basic modes (ACN 817511).

Regional versus major airline pilots. No significant difference was found between the manual flying ability of regional airline pilots versus major airline pilots. The hypothesis proposed that inexperienced regional pilots, who may have been hired with lower total flight hours, did not fully develop the flight skills need to fly a complex aircraft without the assistance of automation. Furthermore, regional pilots may become more and more dependent upon the automation and are lulled into a sense of complacency while using it. However, the statistical testing of the ASRS reports did not support this hypothesis.

In an attempt to limit the total number of potential qualifying reports, the ASRS database search for the years 2001-2010 was purposely limited to those reports identified by ASRS analysts as “unstabilized approach” instead of searching for all reports during the approach and landing phases of flight. This decision was made to prevent the analysis of potentially tens of thousands of reports. There is potential that many hand-flown, unstabilized approach reports were not included in the analysis because the entire ASRS database for this ten-year period was not searched. This difference in reports may have changed the outcome of the chi-square testing.

There were many case-by-case examples where clearly the pilot flying was over-dependent upon the automation that resulted in an unstabilized approach.

> Requiring the use of the autopilot for ALL IMC approaches have made pilots hesitate to turn off the autopilot and just hand fly. The pilots are no longer as proficient as they once were, and their confidence in hand flying an approach is greatly diminished … Automation is a great thing, but sometimes doing it by hand works a lot better, and we could have avoided the missed approach to begin with. The SOPs are too restrictive in this regard. Turning the autopilot on after going missed would have helped a great deal due to the work load and unfamiliar ops. (ACN 854880)

Other times it seemed that new regional pilots never had the opportunity to learn many of the basic maneuvers because their primary flight training was oriented to airline flying emphasizing the use of automation from the very beginning.

> I believe another reason it happened, is the First Officer's lack of experience in entering patterns to controlled fields on a visual, or lack of previous experience entering uncontrolled field patterns. He had less than 300 hours when hired here, no CFI, and went right to the jet, which doesn't do many uncontrolled field or controlled field complete visual patterns. I learned this teaching my students, flying charter, flying my previous airliner (to many uncontrolled fields) and being a former Line Check Airman, which was very helpful in this area, and is some of the experience

> many of our jet First Officer's will never get. We should be hiring CFI's/pilots with more experience. Better visual pattern training in the simulator and on IOE. Better briefs for pattern entry. We discussed the event, and what went wrong. We also discussed what could be done better in future visual patterns for planning, entry, descent, and CRM. He will do better in the future, but I'm not so sure about other inexperienced jet First Officer's. (ACN 844841)

Internationally operating pilots versus United States domestically operating pilots. ASRS reports revealed no statistical difference between the manual flying ability of internationally operating pilots versus domestically operating pilots. Although internationally operating pilots perform fewer landings then their domestic counterparts, the statistical testing did not reveal any increase in the number of unstabilized, hand-flown approaches performed according to ASRS reports.

As mentioned earlier, additional qualifying ASRS reports may have been discovered if the entire database was searched for the ten-year period. In addition, finding a suitable number of qualifying reports that were associated with manual flight was difficult. International operating Captains are usually the most senior pilots in the airline with vast amounts of flight experience. Often pilots understand that the combination of their lack of recent experience and their unavoidable fatigue, even with an augmented crew, would necessitate the need for the assistance of flight automation. Even with the assistance of additional relief pilots and automation, procedural errors occurred such as incorrect flap configurations or forgetting to lower the landing gear.

Occasionally, a pilot would recognize their unfamiliarity with manually flying the aircraft due to lack of recent practice and express their concern.

> "This is a standard VFR pattern, yet one I had not accomplished in nearly 10 yrs. Needless to say, I was rusty on some of the fundamentals … Lesson, don't forget the fundamentals especially on little used approaches." (ACN 521299)

Conclusion

There has been much discussion in the mainstream media about manual flight ability of airline pilots during the time this thesis was written. Recently, two reports have been released indicating that the decline in manual flight skill of airline pilots is recognized throughout the industry and capturing the attention of regulating agencies (Bureau d'Enquêtes et d'Analyses [BEA], 2011; Lowy, 2011).

Most recently, the information recovered from the flight data recorders of Air France Flight 447 revealed a potential breakdown in pilot manual flight skill when the automation failed. According to an interim report released by the French investigative authority, BEA (2011), when the aircraft automation was unable to properly maintain control of the aircraft, the autopilot automatically disconnected, and reverted command back to the pilots. Although the aircraft was in an aerodynamic stall condition, the flight data showed the pilots commanded a nose-up pitch attitude versus a required nose-down pitch attitude to maintain control of the aircraft. This technique is contrary to basic training that every pilot receives during aerodynamic stall training, regardless of aircraft type. Coincidentally, the Captain of Colgan Flight 3407 commanded the same nose-up pitch attitude in response to the same flight condition (NTSB, 2010).

In addition, excerpts from a draft report issued by an FAA advisory committee highlights airline pilots' over-reliance on flight automation and therefore are "'forgetting how to fly'" (Lowy, 2011, p.1). The draft report, after examining accident and incident reports, found that over 60% of accidents and 30% of incidents involved manual flight difficulties or mistakes involving flight automation. The report stated that typical issues involved pilots' inability to recognize flight automation disengaging or the failure to properly monitor and maintain airspeed.

The results of the questions proposed by this thesis are inconclusive, however the research conducted has revealed valuable information on the subject of the decline in manual flight ability of airline pilots. After the review many ASRS reports, some of the main points captured from analyzing the reports are highlighted in the following statements.

- Airspeed deviation was one of the most frequent causes of manually-flown unstabilized approaches, regardless of year, airline size, or airline type. This discovery supports the findings of Ebbatson's research (2009) that speed control is especially susceptible to flight skill decay.

- Pilots seem very dependent upon technology. If there is an issue with the automation, pilots will often opt to solve the automation problem instead of manually flying the aircraft to landing.
- Many times, regional airline pilots are the most dependent upon using flight automation because their operating procedures emphasized its use or their low total flight experience did not allow them to become operationally proficient with manual flight control.
- International pilots are conscious of their lack of flying proficiency and chronic fatigue; therefore they choose to maximize the assistance of flight automation during critical phases of flight.
- Pilots feel that quite often Air Traffic Controllers force them into accepting approach clearances that lead them into an unstabilized approach as the only option to land.
- Pilots also have mission-orientated personalities and will often try to “make it (the approach) work” or “force it” while salvaging a poor approach to landing even if they no longer meet stabilized criteria.

Curry (1985) found that many pilots were apprehensive of the risks involved with implementing new technology into the flight deck. Twenty-five years later, many of those risks seem, as predicted by Curry, to be occurring throughout various elements within the aviation industry. Future research is needed to understand how the pilot operator interacts with current levels of automation before future implementation of additional automation and other technologies are introduced. The FAA envisions aircraft automation as a means to increase the total number of airport operations and maximize the total number of aircraft within the National Airspace System (FAA, 2011). How the proposed use of flight technology and the increase in the number aircraft operating in the same airspace will affect the flight crew has yet to be completely understood. Regardless of the level of sophistication achieved in aircraft automation, the fundamental human-machine interaction continues to be a weak link in the advancement of safety within the industry. Enormous amounts of airline and government funding are being invested to improve fuel efficiency and increase airspace capacity (Karp, 2007), but the importance manual flying skill during primary flight training must not be forgotten. The flying public should trust that a safe and properly trained flight crew will be at the controls for each and every flight, and that trust must not be compromised by the overuse of automation. Pilot manual flight skill can be maintained through awareness of flight skill decay causes, understanding the importance of routine manual flight skill practice, and the implementation of airline procedures or policies to promote more frequent manual flying.

Captain Sullenberger relied upon all his years of experience flying non-automated aircraft when he manually flew the powerless A320 to a successful ditching on the Hudson River in 2008. The next time that automation fails and an aircraft has to be manually flown, it is uncertain if the pilots will have the same depth of flight experience as Captain Sullenberger to bring the aircraft to a successful landing.

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Appendix A: ASRS coding form samples

AIRCRAFT

ATC/Advisory Q

- 118 - FSS ____________
- 110 - Center____________
- 120 - CTAF ____________
- 5032 - Ground ____________
- 116 - Military Facility__________
- 5033 - Ramp____________
- 114 - Tower
- 112 - TRACON
- 122 - UNICOM

Aircraft Operator Q1

- 5034 - Air Carrier
- 5035 - Air Taxi
- 5036 - Corporate
- 5037 - Fractional
- 5038 - FBO
- 5039 - Government
- 5040 - Military
- 5041 - Personal
- 5042 - Other

Flight Plan Q1

- 200 - VFR
- 201 - IFR
- 202 - SVFR
- 203 - DVFR
- 204 - None

Make Model Q1

- 159 - Name____________

Operating Under FAR Part Q1

- 175 - Part 91
- 5044 - Part 103
- 176 - Part 119
- 177 - Part 121
- 178 - Part 125
- 179 - Part 129
- 180 - Part 135
- 5045 - Part 137
- 181 - Other __________

Aircraft Letter Reference Q1

- 90 - X
- 91 - Y
- 92 - Z
- A, B, C, D, E, F, G, H, I, J, K, L, M, N, O, P, Q, R, S, T, U, V, W

AIRCRAFT

Mission Q1

- 210 - Aerobatics
- 211 - Agriculture
- 212 - Ambulance
- 213 - Banner Tow
- 215 - Ferry
- 216 – Cargo/Freight
- 217 - Passenger
- 218 - Photo Shoot
- 219 - Personal
- 220 - Refueling
- 222 - Skydiving
- 223 - Tactical
- 224 - Test Flight
- 225 - Traffic Watch
- 226 - Training
- 5046 - Utility
- 227 - Other ________

Flight Phase

- 5048- Taxi
- 5049 - Parked
- 5050 - Takeoff
- 5051 - Initial Climb
- 5052 - Climb
- 5053 - Cruise
- 5054 - Descent
- 5055 - Initial Approach
- 5056 - Final Approach
- 5057 - Landing
- 5058 - Other____________

Route in Use

- 332 - Direct
- 336 - Oceanic
- 329 - VFR Route
- 328 - Vectors
- 350 - Visual Approach
- 5059 - None
- 331 - Airway ____________
- 340 - STAR ____________
- 325 - SID ____________
- 5060 - Other____________

Events	
Anomaly.Aircraft Equipment	Q1
801 - **Critical**	
802 - Less Severe	
Anomaly.Airspace Violation	Q1
5197 - All Types	
Anomaly.ATC Issues	Q1
5198 - All Types	
Anomaly.Flight Deck/Cabin/Aircraft Event	Q1
879 – Illness	
881 - Passenger Electronic Device	
878 - Passenger Misconduct	
899 - Smoke/Fire/Fumes/Odor	
5199 – Other / Unknown	
Anomaly.Conflict	Q1
852 - **NMAC**	
5200 - Airborne Conflict	
854 - **Ground Conflict, Critical**	
853 - Ground Conflict, Less Severe	
Anomaly.Deviation - Altitude	Q1
812 - Crossing Restriction Not Met	
811 - Excursion from Assigned Altitude	
809 - Overshoot	
810 – Undershoot	
Anomaly.Deviation - Speed	Q1
5201 – All Types	
Anomaly.Deviation - Track/Heading	Q1
5202 – All Types	
Anomaly.Deviation - Procedural	Q1
890 - Clearance	
892 - FAR	
900 - Hazardous Material Violation	
817 - Landing without Clearance	
5203 - Maintenance	
5204 - MEL	
893 - Published Material/Policy	
5205 - Security	
5206 - Weight and Balance	
5207 – Other / Unknown	
Anomaly.Ground Excursion	Q1
813 - Ramp	
814 - Runway	
815 - Taxiway	
Anomaly.Ground Incursion	Q1
818 - Runway	
816 - Taxiway	

Anomaly.Ground Event/Encounter	Q1
5208 - Aircraft	
820 - FOD	
824 - Gear Up Landing	
5209 - Ground Strike – Aircraft	
5210 - **Loss of Aircraft Control**	
5211 - Object	
821 - Person/Animal/Bird	
822 - Vehicle	
5212 – Other / Unknown	
Anomaly.Inflight Event/Encounter	Q1
804 - **CFTT/CFIT**	
5213 - Fuel Issue	
5214 - **Loss of Aircraft Control**	
5215 - Object	
5216 - Bird / Animal	
897 - Unstabilized Approach	
860 - VFR in IMC	
858 - Wake Vortex Encounter	
859 – Weather / Turbulence	
5329 – Other / Unknown	
Anomaly.No Specific Anomaly Occurred	Q1
5218 - All Types	
Anomaly.Other	Q1
901 - Write-in	

Appendix B: San José State University IRB registration

SAN JOSÉ STATE
UNIVERSITY

Division of Academic Affairs

Associate Vice President
Graduate Studies & Research

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One Washington Square
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To: Antonio Puentes

From: Pamela Stacks, Ph.D.
Associate Vice President
Graduate Studies and Research

Date: August 10, 2011

The Human Subjects-Institutional Review Board has registered your study entitled:

"The decline in manual flight skill of modern airline pilots"

This registration, which provides exempt status under Exemption Category 4 of SJSU Policy S08-7, is contingent upon the subjects included in your research project being appropriately protected from risk. Specifically, protection of the anonymity of the subjects' identity with regard to all data that may be collected about the subjects from your secondary sources needs to be ensured.

This registration includes continued monitoring of your research by the Board to assure that the subjects are being adequately and properly protected from such risks. If at any time a subject becomes injured or complains of injury, you must notify Dr. Pamela Stacks, Ph.D. immediately. Injury includes but is not limited to bodily harm, psychological trauma, and release of potentially damaging personal information. This approval for the human subject's portion of your project is in effect for one year, and data collection beyond August 10, 2012 requires an extension request.

If you have any questions, please contact me at (408) 924-2427.

Protocol # S1104030

cc. Kevin Jordan 0120

Appendix C: Flight Safety Foundation copyright release

Notice

The Flight Safety Foundation (FSF) Approach-and-landing Accident Reduction (ALAR) Task Force has produced this briefing note to help prevent ALAs, including those involving controlled flight into terrain. The briefing note is based on the task force's data-driven conclusions and recommendations, as well as data from the U.S. Commercial Aviation Safety Team (CAST) Joint Safety Analysis Team (JSAT) and the European Joint Aviation Authorities Safety Strategy Initiative (JSSI).

The briefing note has been prepared primarily for operators and pilots of turbine-powered airplanes with underwing-mounted engines (but can be adapted for fuselage-mounted turbine engines, turboprop-powered aircraft and piston-powered aircraft) and with the following:

- Glass flight deck (i.e., an electronic flight instrument system with a primary flight display and a navigation display);
- Integrated autopilot, flight director and autothrottle systems;
- Flight management system;
- Automatic ground spoilers;
- Autobrakes;
- Thrust reversers;
- Manufacturers'/operators' standard operating procedures; and,
- Two-person flight crew.

This briefing note is one of 34 briefing notes that comprise a fundamental part of the FSF *ALAR Tool Kit,* which includes a variety of other safety products that have been developed to help prevent ALAs.

This information is not intended to supersede operators' or manufacturers' policies, practices or requirements, and is not intended to supersede government regulations.

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