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Flight-Deck Automation: The Attitudes and Perceptions of Selected Boeing 757/767 Air Carrier Pilots

William Woodrow Clark
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Flight-Deck Automation:
The Attitudes and Perceptions of Selected Boeing 757/767
Air Carrier Pilots

by

William Woodrow Clark

A Thesis Submitted to the
Office of Graduate Programs
in Partial Fulfillment of the Requirements for the Degree of
Master of Aeronautical Science

Embry Riddle Aeronautical University
Daytona Beach, Florida
March, 1995
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Flight Deck Automation: Is It Safe?

The Attitudes and Perceptions of Selected Boeing 757/767 Air Carrier Pilots

by

William Woodrow Clark

This thesis was prepared under the direction of Dr. Henry R. Lehrer, Department of Aeronautical Science, for approval by the Thesis Review Committee. It is submitted to the Dean of Extended Campus in partial fulfillment of the requirements for the degree of Master of Aeronautical Science.

THESIS COMMITTEE:

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Date

Dean of Extended Campus
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ABSTRACT

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Title: Flight-Deck Automation: The Attitudes and Perceptions of Selected Boeing 757/767 Air Carriers Pilots
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Development in electronic displays and computers have enabled avionics designers to present the pilot with ever increasing amounts of information in greater detail and with more accuracy. However, technological developments have not always brought about enhancement of the pilot’s role. Investigating the interaction of cockpit crew members and the vast array of automated systems they control and monitor will contribute to the determination the effect this interface has on the performance of the cockpit team. This study utilized a questionnaire to determine if the opinions of the flight crew suggested performance is impacted negatively by automation. There was no significant agreement suggesting that automation impacted the flight crew performance negatively by inducing complacency, loss of proficiency or by creating an unsafe environment. It did reveal that less experienced pilots were less proficient and felt more overwhelmed with the newer technology incorporating advanced automation.
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CHAPTER I

Introduction

The goal of the airline industry is a simple one. To transport passengers from point A to point B in a comfortable, safe, and optimum manner. Although the goal is simple, the means by which it is accomplished is very complex. A principle facet in this endeavor is the interaction between the pilot, crew members, and the automated systems they control or monitor. It is the breakdown within this interface where many of the errors occur which lead to aviation mishaps.

More than two-thirds of all air carrier mishaps are attributed to pilot error (Stix, 1991). Another source suggests that seventy percent of the cases of airline accidents may be traced to human factors in crew performance. The remaining thirty percent may be linked to technical problems where human factors may also have been a factor (North, 1992). This rate is even higher for general aviation where almost 9 out of 10 mishaps are attributed to pilot error (Nagel, 1988). To rectify this, aircraft designers and operations managers utilize cockpit automation to reduce the number of human errors. The impetus is to "automate human error out of the system" (Curry, Wiener,
1980). The belief is that control devices are extremely good at real-time control, but must be supported by the remarkable flexibility of the human as supervisor and standby controller, in case of breakdown or other unforeseen events (Curry, Wiener, 1980).

Recent research has shown that automation, implemented with insufficient consideration to the human factors interface, can frequently create more problems than it solves (Bergeron, Hinton, 1985). The new cockpits realign work more than relieve it. Programming a computer to fly the aircraft results in a shift in the role of the pilot from one of controller to one of monitor (Hughes, 1992a, in press-a). Humans have proven that they are not so good at the monitoring task and are highly likely to miss critical signals, as well as to make occasional commissive errors (Curry, Wiener, 1980).

There are many human factors areas involved in pilot error in which investigation is warranted: flight station organization, crew interaction, fitness for duty (fatigue, health), judgment, sensory illusion, distractions, and complacency induced by reliability of equipment (Lederer, 1988). These factors singularly or in combination have a tremendous impact on the pilot. To limit the scope, this thesis will focus on the complacency and loss of proficiency induced by automation, and any safety consequences that result from this interface.
Statement of the Problem

Development in electronic displays and computers have enabled avionics designers to present the pilot with ever increasing amounts of information in greater detail and with more accuracy. There is evidence that this new technology may change the pilot's workload to the detriment of performance.

Significance of the Problem

Degradation of the pilot's performance during flight is the opposite result sought by those incorporating automation into the flight compartment. Detracting from the ability of a flight deck crew member to perform optimally increases the opportunity for this trend to continue. It is apparent that the study of the effect flight-deck automation has on pilot performance is one of dire concern to commercial, military and general aviation aircraft designers, managers and operators.

Review of the Literature

Benefits of automation. The benefits of automation are quite numerous. They may be categorized into two types. First, automation allows certain functions to be performed that could not be accomplished otherwise. Second, automated systems are often able to provide more precise performance than humans (Boehm- Davis, Curry, Harrison, Wiener, 1983). Accepting automation as an actual improvement to aviation, designers and system operators find several reasons for its implementation.
First, the improvement of microprocessor technology has enabled the aircraft designer to incorporate equipment which are smaller, cost less, use less power, and perform more reliably and precisely than the traditional manual equipment. This specifically addresses the problem of economy of cockpit space. It also provides display flexibility and more precise flight maneuvers and navigation.

Second, economy of operation, improved reliability and decreased maintenance are directly improved. The flight profiles flown via computer are more precise and provide for exacting fuel efficient flight paths. The improved electronic equipment have experienced less down time than their analog counterparts. This directly decreases the amount of maintenance required.

Third, safety considerations are always an issue, especially when over two-thirds of the mishaps are attributed to pilot error. Autopilots, flight directors, and alerting and warning systems are examples of automatic systems that have had a beneficial effect on pilot safety margins. The ground proximity warning system (GPWS) is an excellent example. It was mandated by Congress in 1974 and has been responsible for a major reduction in terrain strikes as a result (Curry, Wiener, 1980).

Lastly, the reduction of pilot workload is believed to be a direct outcome of this automation. By relieving the pilot from the routine manual controlling and calculations,
they are free to more effectively supervise the flight and to concentrate and act more precisely during an emergency. Automation also frees the pilot during the most critical aspect of the flight, descent to landing, and allows them to keep their heads out of the cockpit and scan for other aircraft. Also as important is the performance of tasks in the new two-pilot wide-body aircraft that were previously done with three. Here it is particularly essential that automated systems take up the slack and reduce the workload.

Reducing workload is a phrase often associated with flight station automation, but might be a misnomer. The role shifts from one of hands-on operator to one of monitor. While it is true that this reduces physical workload, cognitive processes are increased due to monitoring. A survey of 100 Boeing 767 pilots from three airlines reflects the controversy over this issue. When asked if "automation reduces overall workload," 47 percent agreed and 36 percent disagreed. Similarly, 53 percent agreed and 37 percent disagreed that "automation does not reduce overall workload, since there is more to keep watch over" (Curry, 1984). One airline captain stated "I’ve never been so busy in my life, and someday this stuff is going to bite me" (Phillips, 1992).

**Automation induced problems.** The thoughts of pilots with regards to automation is of mixed blessings. The innovations have made flying very efficient, but the flip side is reflected in this anecdote: the new design puts a
man and a dog in an airplane. The dog is there to bite the pilot if the man so much as tries to touch the controls. The pilot’s one remaining job is to feed the dog (Stix, 1991). Automation has not gone this far, but the effect it has on the pilot requires attention. Other than take-off and landing, the pilot’s role is basically reduced to one of systems monitor. The role of controller and monitor not only require different skills, but are also in conflict with one another. Controlling the system requires proficiency in the manual skills. Prolonged use of the automatic mode may lead to a deterioration of manual skills, the same skills which might be required due to systems failure or another emergency.

The longer the pilot acts as a monitor, the more degraded his performance will become. During long transits the pilots are less challenged, prone to boredom, complacency, and in extreme cases falling asleep (Boehm-Davis, Curry, Harrison, Weiner, 1983). Studies have shown that 55.2 percent of all aircraft mishaps occur during the descent through final approach phase (Nagel, 1988). This is the most critical phase of flight, immediately following the period of peak complacency during the monotonous monitoring phase of the transit. Staying with or ahead of the aircraft when monitoring is a constant battle against boredom and complacency. The time required to "catch up" with the aircraft during the final phase and particularly during an emergency may be unavailable.
One study was conducted to determine the effect of variations in the reliability of an automated monitoring system on human operator detection of automation failures. Two groups were utilized, one with constant-reliability automation detection and one with variable-reliability automation detection. Subjects performed manual tracking and fuel-management tasks along with system-monitoring which was under automation control. Automation reliability, or the percentage of system malfunctions detected automatically, was held constant over time at a high or low level, or was alternated over time from low to high with the groups respectively. The results indicated that the group with the constant-reliability of automation failures were significantly worse than the variable-reliability group. The study provided empirical evidence of the consequences of automation-induced complacency on pilot performance (Molloy, Parasuraman, Singh, 1993).

These problems are more pronounced with highly automated aircraft such as the Boeing-767. Certain tasks are more complicated to direct via the automated system than to perform manually. There has been a tendency for crews to attempt to program their way out of trouble with the automatic devices instead of disengaging and flying manually. This tendency exacerbates the deterioration of piloting skills due to the overuse of automation. It also creates a perception among pilots of "loss of control" or being "out of the loop" (Wiener, 1985). For example, one
pilot was asked by air traffic control to intercept an airway. The flight management system (FMS) provides no convenient way of performing this task. By the time the pilot figured out he could not, they were long past the airway (Hughes, 1992b, in press-b).

Boeing is working to reverse this perception with the design of the Boeing 777. Their belief is that advances in automation should be evolutionary and strive to maintain the pilot in the decision loop. They are trying to design the flight deck that is appropriate to the pilot’s operation and to enhance their situational awareness. To combat the specific criticism that the crew spends excessive amounts of head-down time scanning instruments, Boeing implemented several solutions which include the streamlining of (FMS) computer functions, the use of colors consistent between displays and the incorporation of data link ("Avionics Companies," 1992). Data link specifically reduces heads-down time by linking the FMS computer with the communications facilities, automatically incorporating frequency changes and recording information and instructions (O’lone, 1992).

Results of two other studies provide information of the difficulty pilots have with the understanding and operation of the FMS. The pilots did become proficient in the standard use of the system, but again had difficulty tracking its status and predicting its behavior during certain aspects of the flight. Difficulties with the
understanding of the functional system structure were also revealed. This again supports the need for better system design (Sarter, Woods, 1992).

The design to limit the response to control inputs to maintain the aircraft within its safe operating envelope is a perfect example of this perception problem. This design has benefits and limitations which model the larger problem as a whole. The ability of an automated system to override pilot inputs are desirable in situations such as an encounter with wind shear. The Airbus Industrie uses fly-by-wire on its A320 in part because of the increased safety it offers through the flight envelope and for wind shear protection (Lenorovitz, 1992).

Wind shear is a phenomena associated with thunderstorms in which extreme downward airflow forces the aircraft to lose altitude. Here, the pilots must react quickly with large control forces to prevent ground impact. The largest danger is the possibility of stalling the aircraft while performing the escape procedures. By limiting the control inputs to those which will not produce a stall, the pilots are confident of flying to the edge of the envelope.

The flip side occurs during evasive maneuvering to avoid a midair collision. By limiting inputs to those within design parameters, the pilots may be unable to avoid impact. In this scenario it would obviously be better to over-stress the aircraft and avoid a mid-air collision.
It is important that the issue of skills deterioration be revisited. The problem results not only from the failure to perform the manual skills on a routine basis, but at the same time, it is partially neglected during training. The development of a training program is difficult due to the dual capacity of the pilot: one as monitor of the system in the fully automatic mode, and one as controller of the system during any other mode. Determining the degree of training for off-line manipulation of the system is a difficult problem. The scenarios practiced during training may not occur, or occur with a sufficient span of time to preclude the pilot’s proficiency.

The difficulty with training is also hampered by the mixture of old and new equipment in the cockpits. Training programs which implement the latest in automated devices serve little purpose for a flight officer assigned to an older generation aircraft.

**Automation consequences.** The aviation community is replete with mishaps attributed to pilot error. What must be considered is if the airplanes are too complex. Did automation in trying to eliminate pilot error create other errors by inducing overload, complacency or lack of proficiency? Presentation of examples should help in such analysis.

The Lockheed L-1011 that crashed in the Florida Everglades in 1972 (NTSB, 1973) is an example of a system failing and the subsequent failure of the pilots to detect
it. The autopilot disengaged and the aircraft entered a gradual descent while in holding which resulted in impact with the ground. The crew were distracted by a landing gear emergency. This type of emergency does not require an immediate action and is considered a deferred malfunction. This means there is time to evaluate the malfunction and determine a proper course of action. Due to the inattention of the crew and subsequent failure to recognize the loss of the autopilot control of the aircraft altitude, the aircraft and all aboard were lost. It has been suggested that prior use of this automatic system induced the complacency of the crew to accept the invulnerability of the automation, and therefore divorce its function from their attention.

The Korean Air Lines flight 007 shot down by a Soviet military aircraft while flying in Soviet airspace is another good example. The determination of the cause was considered to be the incorrect position entered into the inertial navigation system (Bailey, 1989). The failure of the crew to properly monitor their position via traditional means as a backup to the inertial guidance is another form of complacency. The crew could possibly have lost the ability to perform such a function due to their complete reliance upon the system. This complacency and lack of proficiency if induced by automation may manifest itself in future incidents and accidents. With the enormous numbers of people and equipment flying the skies of today and the future, it is imperative that the interactions between the
operators and their equipment be investigated to the most meticulous detail.

**Automation defined.** Automation as used in this study is the utilization of equipment and devices to perform tasks originally accomplished by the pilot. The continuous advances in the aerospace industry in the field of airframes, systems and avionics have burgeoned into the ultra-modern cockpits of today. The fully automated aircraft include equipment performing every possible function. The "Glass Cockpit" of the most advanced aircraft introduce an entirely new design of flat displays, computer management and redundant systems to assist the pilot in the most efficient, effective and optimum way possible. It is not the intention of this study to determine the effect that a specific piece of equipment or a certain cockpit configuration has on the performance of the flight crew. It is the intention to determine the overall impact automation has on the flight crew performance and their interaction with such technology. Therefore, automation is defined as equipment utilized by a cockpit crew member to perform tasks previously performed by the pilot. This allows for the differences in opinions as to what truly is automated, and enables each individual pilot to express their personal interaction with the equipment.

**Statement of Hypotheses**

If the increase in flight-deck automation impacts the pilot in such a way as to induce complacency, loss of
proficiency or to create an unsafe environment, then it will be manifest in the attitude of the flight deck crew. There is no significant difference between the responses of the pilots from American Airlines (AAL) and the pilots of Delta Air Lines (DAL) nor between the captains and first officers.
CHAPTER II

Method

Subjects

Definition of the population incorporating flight-deck automation was determined by the definition utilized to describe the automation. As mentioned, most aircraft incorporate some degree of automation in the design of the flight deck. This automation was found in varying degree within the military, commercial and general aviation aircraft designs. The scope of this thesis was not to generalize to all three categories, and hence was narrowed to the commercial carrier aircraft community.

This commercial carrier population was also considerably varied and included many platforms with varying degree of cockpit automation. The objective was to analyze the effect automation within the cockpit has on pilot performance, and to determine whether that automation was a benefit or a detriment, with particular emphasis on safety. Therefore, some degree of differentiation was needed to achieve this determination. The population was thus defined in the following manner.

Subjects for this study were selected from the population of pilots who currently utilize two specific
platforms, the Boeing 757 and the Boeing 767. These platforms were selected due to the similar design and Federal Aviation Administration (FAA) aircraft type rating criteria. One type rating is utilized for both cockpits. The population was further narrowed to include only carriers located within the United States. The sample of subjects were stratified by carrier, with subjects selected according to availability.

The preferred method was to obtain the exact number of pilots within each carrier flying this specific equipment and select a random sample from each utilizing a table of random numbers. This research was classified as descriptive and a sample size of ten percent was appropriate. Obtaining these numbers and the required information to include the subjects in the sample was hindered by the privacy maintained within each company.

The limited resources of the author required further reduction in sample size and location. The resulting approach was narrowed to target the three major carriers; American Airlines, Delta Air Lines and United Airlines, located in the local vicinity. The Los Angeles International Airport (LAX) was selected and permission was secured to conduct the survey for American and Delta pilots only. Each carrier consisted of approximately 200 pilots domiciled at LAX flying the selected equipment, 75 of which were selected from each for the study. The 75 were than randomly selected by no established pattern.
It is obvious that bias exists in the selection of subjects for the sample population. Convenience sampling was utilized to generate the group which created significant bias due to the non-probability of the sampling technique. This bias was increased due to the utilization of carriers within the vicinity of the author. This limited the geographic exposure as well as the number of different carriers there were to choose from. These factors were important since each carrier has its own training program addressing many of the issues investigated in this study in a significantly different manner.

**Instruments**

A questionnaire was developed to collect information from pilots of the Boeing 757 and 767 aircraft. The questions were directed at the effect automation is having on individual performance, cockpit coordination and management, safety issues, and overall impact. The instrument was created specifically for this study, and thus validity and reliability data are unavailable. A pilot study was conducted to determine the appropriateness of content, clarity of instruction, and effectiveness of obtaining the desired information prior to the instruments finalization and delivery.

Research of this nature required development of an instrument since specific information was needed in this unique field. The reliability of this instrument is dependent upon the individual interpretation of the relative
scale agreement or disagreement for a each question. The cover letters with instructions as well as the questionnaire are included for critical review in Appendix B and C respectively.

**Design**

This thesis is classified as evaluation, utilizing the systematic process of collecting and analyzing data in order to make decisions. This evaluation assessed the current environment in one of the most advanced platforms flying today. The natural setting characteristic of this particular evaluation precluded the control prevalent in most research. Hence, the sole purpose of this evaluation research was to facilitate better decision making for future cockpit design.

This thesis design was chosen because of the inherent complexities, associated with cockpit management and piloting skills. Elaborate methods of conducting experimental analysis have been undertaken, but the funds for these endeavors were vast in comparison to those available for this study. Companies and agencies have expanded on the central idea of this thesis utilizing wide differences in design to achieve essentially the same objectives.

There are numerous variables which could not be controlled in this design, or were beyond its scope. The large variation in cockpit utilization of automation was one. This was reduced by the selection of a specific population and aircraft, which subsequently detracts from
the ability to generalize from the study. Also, the procedures performed by flight crews are carrier dependent, and the study was incapable of addressing individual differences. The forthright honesty of the respondents was also a variable, since it cannot be determined through observation if the responses match the actual environment occurring in flight.

Procedures

A pilot study was conducted introducing the questionnaire developed for the study. Pilots from numerous airlines and platforms were utilized. These pilots were fellow Reserve Naval Aviators attached to Patrol Squadron 65 at the Naval Air Weapons Station (NAWS) Pt. Mugu, California. Feedback from these pilots helped finalize the questionnaire.

The sample population was then selected from the available population of pilots at the Los Angeles airport. Three major carriers were targeted according to their accessibility. These were American Airlines, Delta Air Lines and United Airlines. Permission and assistance was requested from each of the three carrier Chief Pilots by fellow pilots who hand delivered the questionnaire and appropriate cover letter. Personal contact was then made asking permission to conduct the survey, and to request that the Chief Pilots provide any required assistance to the selected pilots. American and Delta gave approval. It is interesting to note that the reluctance of United was due to
the recent broadcast of the vulnerability of the Traffic Alert and Collision Avoidance System (TCAS) depicting negative attitudes toward the equipment. This airline felt that the facts were misrepresented in the program and hence refused to participate in this study to preclude a similar occurrence.

The carrier specific cover letters were then produced and delivered with appropriately labeled, self-addressed, stamped return envelopes along with the questionnaires. Each packet was numbered and then hand delivered into individual pilot mailboxes at the LAX hub according to the depiction indicating the platform flown by the pilot. The questionnaires were randomly distributed at whim. No identifying criteria were collected. The subjects were given two weeks to complete the study.

The questionnaire collected information concerning the pilots' utilization of automated equipment, their general and specific attitude towards its usage, and specific impacts that automation has on piloting. Analysis of this information determined if there was significant agreement on the impact that automation is having on pilot performance and safety.
CHAPTER III

Data Analysis

The data collected from this questionnaire is defined as nominal data, with answers given according to a relative, ordinal scale. The nominal data consists of true categories for the first two questions, cockpit position and years experience, followed by artificial categories for the remainder. The artificial categories allow for a one of five choice in varying degrees of percentages or agreement for a specific question/statement. The data collected may be considered ordinal by classifying the responses in terms of the amount by which they agree, however they are truly nominal and hence limit the type statistics which may be performed.

The population as previously defined are represented by the sample selected for this study. This sample of the population provided the data necessary to perform the statistical computations. This study utilized percentage response calculations and the chi-square ($X^2$). The latter calculation is a nonparametric test of significance, and was utilized to determine if there were significant differences between the groups involved in the study. This allowed for
a combination of comparisons and relationships to be determined from the data collected.

First, the data was stratified into two separate groups, the pilots of American Airlines (AAL) versus the pilots of Delta Air Lines (DAL). The outcome of these calculations determined if the questionnaires could be combined or kept separate for additional comparisons. Specifically, if there was no significant difference between the pilots of the two airlines on a particular question, then the entire number of respondents were combined on that specific question to determine the next comparison.

The second step was the comparison between the captain and first officer positions. If there was a significant difference between the two airline groups on a specific question, then two separate calculations were made to make comparisons within each carrier. This was necessary to allow for the proper application of inferences from the data. For a summary of the outcome of these calculations, refer to appendix A.

**Demographics**

Sample size. Of the one hundred fifty questionnaires delivered, seventy-five per carrier, forty-nine were returned from American and fifty-two from Delta. American respondents were comprised of twenty-seven captains and twenty-two first officers. Delta consisted of twenty-four
captains and twenty-eight first officers. Table 1 lists the years experience of the pilots responding.

Table 1

<table>
<thead>
<tr>
<th>Years experience in the B-757/767</th>
<th>Response (Years) N(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
</tr>
<tr>
<td>----------------------------------</td>
<td>---</td>
</tr>
<tr>
<td>American</td>
<td></td>
</tr>
<tr>
<td>Captain</td>
<td>27</td>
</tr>
<tr>
<td>First Officer</td>
<td>22</td>
</tr>
<tr>
<td>Delta</td>
<td></td>
</tr>
<tr>
<td>Captain</td>
<td>24</td>
</tr>
<tr>
<td>First Officer</td>
<td>28</td>
</tr>
</tbody>
</table>

*N is the number of respondents answering this category and the respective percentage of the total responding. Total number of respondents from this group.

There was a significant difference in the number of years experience between the carriers. Hence, we reject the null hypothesis that there was no significant difference with the experience level of these pilots. Specifically, American consisted of thirty-three pilots with one to four years experience in the Boeing 757/767 and fourteen with five or more years. Delta consisted of thirty pilots with
two or less years experience in the same cockpit and sixteen with five or more years.

Additionally, there was a significant difference found between the years experience between the captains and first officers for the pilots of Delta. Twenty-one of the thirty Delta pilots with two years or less experience were first officers. Eleven of the fourteen with six or more years were captains. The captains have significantly more experience than the first officers for Delta at the LAX hub. It is necessary to be particularly alert to this difference to determine if there are significant differences between these two groups on the remaining questions.

To begin the search for data suggesting that extensive automation usage may create an unsafe environment, the first step was to determine the perception that the users have of the equipment. Thus far, we have defined a population that is varied in experience and equally divided in cockpit position.

**Automation composition.** When asked what percentage of flying skills are automated, seventy-two percent of the pilots responding said that greater than half of the tasks were automated. One Delta pilot stated that "everything from above 18000' to the final approach fix (FAF)-unless it is in the way", was automated. An American pilot stated that "virtually all pilot actions can be automated, however, pilots that wish to maintain proficiency will seldom depend on automated systems during critical phases of flight
Table 2

<table>
<thead>
<tr>
<th>Group</th>
<th>n^b</th>
<th>&lt;25</th>
<th>25-50</th>
<th>51-75</th>
<th>76-90</th>
<th>&gt;90</th>
</tr>
</thead>
<tbody>
<tr>
<td>American</td>
<td>47</td>
<td>1 (2)</td>
<td>11(23)</td>
<td>15(32)</td>
<td>18(38)</td>
<td>2 (4)</td>
</tr>
<tr>
<td>Delta</td>
<td>50</td>
<td>6(12)</td>
<td>9(18)</td>
<td>15(30)</td>
<td>14(28)</td>
<td>6(12)</td>
</tr>
</tbody>
</table>

^aN is the number of respondents answering this category and the respective percentage of the total responding. ^bTotal number of respondents from this group.

When asked what percentage of time that the pilot utilized these automated systems, sixty-three percent of the American pilots said that greater than seventy-six percent of the time automation is used. Only forty-seven percent of the Delta pilots said that more than seventy-six percent of the time they used automation, while eighty-four percent said greater than fifty percent of the time they used it. One pilot drew a graph of cockpit workload during the entire flight and then delineated the percentage time that automation is used. That representation summarized the position of most of the respondents and indicated that a pattern of automation use occurs throughout the flight.
This pattern depicted that automation was available throughout the flight evolution, but was completely dependent upon personal choice of whether the automation was utilized. Table 3 lists the responses to this question.

Table 3

<table>
<thead>
<tr>
<th>Response (Percentage)</th>
<th>N(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group</td>
<td>&lt;25</td>
</tr>
<tr>
<td>American</td>
<td>49</td>
</tr>
<tr>
<td>Delta</td>
<td>52</td>
</tr>
</tbody>
</table>

aN is the number of respondents answering this category and the respective percentage of the total responding. bTotal number of respondents from this group.

Having questioned the amount of automation and the time required to utilize it, a probe into the general attitude the user has towards its implementation was in order. The next question asked if the pilots felt that too many activities were automated. Fifty-eight percent of all pilots stated that they disagreed. Seven percent strongly disagreed while twenty-five percent were neutral. Refer to table 4 for comparison.
Table 4

Are too many systems, procedures, tasks automated?

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>SD</th>
<th>D</th>
<th>N</th>
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</tbody>
</table>

Note. SD = strongly disagree; D = disagree; N = neutral; A = agree; SA = strongly agree. *N is the number of respondents answering this category and the respective percentage of the total responding. bTotal number of respondents from this group.

The survey now began to focus and exact more specific information from the respondents. The next group of questions were utilized to attack the crux of the research hypothesis.

Safety impact. The pilots were asked point blank if any form of automation created an unsafe environment in the cockpit. There was a significant difference between the pilots of American and Delta with their responses to this question. There was no clear line of support or lack of support for this question as depicted in Table 5.
Table 5

<table>
<thead>
<tr>
<th>Group</th>
<th>$n^b$</th>
<th>SD</th>
<th>D</th>
<th>N</th>
<th>A</th>
<th>SA</th>
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<td>8(30)</td>
<td>9(33)</td>
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<td>0(0)</td>
</tr>
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<td>8(38)</td>
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<td>4(17)</td>
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<td>0(0)</td>
<td>8(29)</td>
<td>5(18)</td>
<td>13(46)</td>
<td>2(7)</td>
</tr>
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</table>

Note. SD = strongly disagree; D = disagree; N = neutral; A = agree; SA = strongly agree. *N is the number of respondents answering this category and the respective percentage of the total responding. $^b$Total number of respondents from this group.

Thirty-five percent of the American pilots disagreed and thirteen percent strongly disagreed that automation created an unsafe environment in the cockpit. Similarly, thirty-eight percent Delta pilots disagreed as well. Conversely, twenty-nine percent of American pilots agreed with the question while forty percent Delta pilots agreed and four percent strongly agreed. Several of the comments suggested that the automation could create such dangers when familiarity was less and a pilot was still learning the
system. One pilot said "until the last couple of years when we were taught automation download, there were too many guys playing with the FMS below 10,000’ in high density environment. Now most of us use manual auto flight functions when changes need to be made to the FMS in high density airspace below 10,000’".

This last question was not definitive hence the pilots were asked if a specific task performed by automation created a situation requiring manual backup or performance of the task using basic pilotage. Sixty-eight percent of all pilots agreed and twelve percent strongly agreed. One pilot said that "the professional pilot is always mentally flying the aircraft; therefore, he backs up automation with pilotage". Table 6 lists the responses to this question.

Table 6

Has any automated task required manual backup?

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>SD</th>
<th>D</th>
<th>N</th>
<th>A</th>
<th>SA</th>
</tr>
</thead>
<tbody>
<tr>
<td>American</td>
<td>47</td>
<td>0</td>
<td>6</td>
<td>4</td>
<td>32</td>
<td>5</td>
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<tr>
<td>Delta</td>
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<td>0</td>
<td>5</td>
<td>5</td>
<td>35</td>
<td>7</td>
</tr>
</tbody>
</table>

Note. SD = strongly disagree; D = disagree; N = neutral; A = agree; SA = strongly agree. "N is the number of respondents answering this category and the respective percentage of the total responding. Total number of respondents from this group."
To continue this line of questioning, more specific questions regarding the use of automation were utilized. These questions were aimed at obtaining responses to the specific instances that may have caused difficulties or worse. The use of the majority of the cockpit equipment requires a pilot to perform tasks inside the cockpit with their full attention applied to the problem, task or procedure. Many incident reports have documented near misses of aircraft while airborne as well as during ground evolutions. Hence, this was a logical continuance of the investigation.

Specific equipment impact. The pilots were asked if the flight management computer kept them inside the cockpit too much, particularly during the low altitude phases of flight during higher traffic volume. There was a significant difference between the responses of the American and Delta pilots on this question. Fifty-five percent of American pilots disagreed when asked if the flight management computer (FMC) kept them inside the cockpit too much instead of outside scanning for aircraft. One American pilot stated that "until the pilot is very familiar with the FMC, too much time is spent inside the cockpit during critical phases of flight. However, as experience increases in type, a transition occurs where more time can be spent outside the cockpit".

Thirty-three percent of Delta pilots agreed and the same number disagreed on the same question. One pilot said
that "if you followed company procedures below 10,000', this is no problem". Another pilot said that the FMS designer did not consider runway changes in the equipment development, which was suggested by several other pilots. One comment iterated that last minute changes and re-routes as well as runway changes could be distracting, let alone any kind of emergency or inclement weather. The results of this question are listed in Table 7.

Table 7
Flight management computer's impact on outside scan

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>SD</th>
<th>D</th>
<th>N</th>
<th>A</th>
<th>SA</th>
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<td>16 (59)</td>
<td>3 (11)</td>
<td>5 (19)</td>
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</tr>
<tr>
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<td>0 (0)</td>
<td>11 (50)</td>
<td>4 (18)</td>
<td>7 (32)</td>
<td>0 (0)</td>
</tr>
<tr>
<td>Delta</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Captain</td>
<td>23</td>
<td>0 (0)</td>
<td>9 (35)</td>
<td>5 (22)</td>
<td>10 (43)</td>
<td>0 (0)</td>
</tr>
<tr>
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<td>28</td>
<td>5 (18)</td>
<td>8 (29)</td>
<td>8 (29)</td>
<td>7 (25)</td>
<td>0 (0)</td>
</tr>
</tbody>
</table>

Note. SD = strongly disagree; D = disagree; N = neutral; A = agree; SA = strongly agree. "N is the number of respondents answering this category and the respective percentage of the total responding. \(^b\) Total number of respondents from this group.
The next question was related to this last one and received similar responses. Forty-one percent of all pilots disagreed that automation requirements were too time consuming particularly during the critical phases of flight. Twenty-seven percent agreed however while six pilots wrote comments that the time requirements could be dangerous, but only if you allowed them to be. The responses for this question are listed in Table 8.

Table 8

Automation time requirements for critical phases of flight

<table>
<thead>
<tr>
<th>Group</th>
<th>( n^a )</th>
<th>SD</th>
<th>D</th>
<th>N</th>
<th>A</th>
<th>SA</th>
</tr>
</thead>
<tbody>
<tr>
<td>American</td>
<td>49</td>
<td>2 (4)</td>
<td>24(49)</td>
<td>12(24)</td>
<td>10(20)</td>
<td>1(2)</td>
</tr>
<tr>
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<td>52</td>
<td>6(12)</td>
<td>17(33)</td>
<td>13(25)</td>
<td>15(29)</td>
<td>1(2)</td>
</tr>
</tbody>
</table>

Note. SD = strongly disagree; D = disagree; N = neutral; A = agree; SA = strongly agree. \(^a\)N is the number of respondents answering this category and the respective percentage of the total responding. \(^b\)Total number of respondents from this group.

Many ideas have been developed to help alleviate these last two problems by creating procedures and/or equipment to assist the pilots during the more critical phases of flight. This next piece of equipment is one such device and has also been in the spotlight previously. Fifty-two
percent of all pilots disagreed and thirteen percent strongly disagreed when asked if TCAS deterred a good look out doctrine. Of the eighteen percent of pilots that agreed, forty-three percent disagreed or strongly disagreed and forty-seven percent were neutral when asked if this dependency will lead to an aviation mishap. The majority of the comments supported the equipments’ use and praised the capabilities and performance of the TCAS. One Captain stated "TCAS is a great tool. I’ve seen more aircraft than I’ve ever seen before. At least when you are alerted, it does get your eyes out of the cockpit and gives a general place to look. I think it greatly increases situational awareness. In my cockpit, we NEVER rely just on TCAS, though". The responses to the first question about TCAS are listed in Table 9. Question #16 is not tabulated.
Table 9

Does TCAS dependency substitute a good lookout doctrine?

<table>
<thead>
<tr>
<th>Group</th>
<th>n^b</th>
<th>SD</th>
<th>D</th>
<th>N</th>
<th>A</th>
<th>SA</th>
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</thead>
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<tr>
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<td>9(18)</td>
<td>25(51)</td>
<td>6(12)</td>
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<td>27(52)</td>
<td>12(23)</td>
<td>9(17)</td>
<td>0 (0)</td>
</tr>
</tbody>
</table>

Note. SD = strongly disagree; D = disagree; N = neutral; A = agree; SA = strongly agree. "N is the number of respondents answering this category and the respective percentage of the total responding. "Total number of respondents from this group.

Flight proficiency and workload. This next question is often asked and is of an ongoing concern with the FAA, the airlines and the pilots as well. There are many advocates of automation but even within their ranks, the topic of skills deterioration is of utmost concern. There was a significant difference with the responses between the pilots of American and Delta on the critical question of whether automation use was causing deterioration of manual flying skills. The results produced forty-nine percent disagreement from American and twenty-nine percent disagreement from Delta pilots. Thirty-five percent American and thirty-eight percent Delta pilots agreed however. The comments varied equally as well. Several
comments stated that the professional pilot will fly the aircraft manually enough to remain proficient. At the same time, several other comments suggested that there is no standard to maintain manual proficiency and that many pilots do not fly manually unless they have to. Table 10 lists the responses to this critical question.

Table 10

Is automation causing the deterioration of manual skills?

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>SD</th>
<th>D</th>
<th>N</th>
<th>A</th>
<th>SA</th>
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<tbody>
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<td></td>
<td></td>
<td></td>
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<tr>
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<td>14(52)</td>
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<td>3(14)</td>
<td>10(45)</td>
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<td>Delta</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Captain</td>
<td>24</td>
<td>0</td>
<td>7(29)</td>
<td>6(25)</td>
<td>11(46)</td>
<td>0 (0)</td>
</tr>
<tr>
<td>First Officer</td>
<td>28</td>
<td>5(18)</td>
<td>8(29)</td>
<td>6(21)</td>
<td>9(32)</td>
<td>0 (0)</td>
</tr>
</tbody>
</table>

Note. SD = strongly disagree; D = disagree; N = neutral; A = agree; SA = strongly agree. *N is the number of respondents answering this category and the respective percentage of the total responding. Total number of respondents from this group.

When asked specifically if they fly the aircraft manually frequently enough to maintain skills at a level capable of performing functions off-line during an
emergency, fifty-eight percent of all pilots agreed and twenty-six percent strongly agreed that they did. Only twelve percent disagreed. The replies for this question are in Table 11.

Table 11

Proficiency level of manual skills sufficient to perform emergencies

<table>
<thead>
<tr>
<th>Response (Percentage) N(%)</th>
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</tr>
</thead>
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</tr>
<tr>
<td></td>
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<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Delta</td>
<td>52</td>
</tr>
</tbody>
</table>

Note. SD = strongly disagree; D = disagree; N = neutral; A = agree; SA = strongly agree. aN is the number of respondents answering this category and the respective percentage of the total responding. bTotal number of respondents from this group.

The next question asked if automation increases the pilots' workload. There was a significant difference with the responses between the pilots of American and Delta. Sixty-one percent of the American pilots disagreed that automation increases workload. Forty-six percent of the Delta pilots agreed that workload was increased. The comments continue this disparity by suggesting that different phases of flight as well as different situations
create different levels of work. One pilot stated "automation reduces workload (for the better) during low stress periods. However, during high workload periods such as descent/approach with minor or major flight plan changes, automation can become a problem. During high work load periods I think it is better to decrease use of FMS and revert to basic flying procedures. It is less stressful and keeps ones eyes out of the cockpit. Automation may increase work load during high activity periods because we have to monitor what we put into the FMS, what it is doing, and monitor the airplane". The results of this question are listed in Table 12.

Table 12

<table>
<thead>
<tr>
<th></th>
<th>Response (Percentage) N(%)</th>
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<tr>
<td></td>
<td>G</td>
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<tr>
<td>American</td>
<td>48</td>
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<tr>
<td>Delta</td>
<td>52</td>
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</table>

Note. SD = strongly disagree; D = disagree; N = neutral; A = agree; SA = strongly agree. a N is the number of respondents answering this category and the respective percentage of the total responding. bTotal number of respondents from this group.
The next questions address the second and equal area of concern for those supporting automation and those opposing. The environment where tasks are performed by machines creates the situation where one is concerned that the operator may grow dependent upon that function, and eventually lose all precaution to the equipments vulnerability.

**Induced complacency.** When asked if extensive use of automation will induce complacency, fifty-seven percent of all pilots agreed while nine percent strongly agreed. Every comment stated similar responses, that the professional pilot will not allow this to happen by flying the aircraft manually or performing other tasks manually. Table 13 lists the responses to this latest question.

### Table 13

**Does automation induce complacency on the flight deck?**

<table>
<thead>
<tr>
<th>Response (Percentage) N(%)</th>
<th>Group</th>
<th>n</th>
<th>SD</th>
<th>D</th>
<th>N</th>
<th>A</th>
<th>SA</th>
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<td>1 (2)</td>
<td>10(20)</td>
<td>5(10)</td>
<td>29(59)</td>
<td>4 (8)</td>
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<tr>
<td></td>
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<td>2 (4)</td>
<td>8(15)</td>
<td>9(17)</td>
<td>28(54)</td>
<td>5(10)</td>
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**Note.** SD = strongly disagree; D = disagree; N = neutral; A = agree; SA = strongly agree. "N is the number of respondents answering this category and the respective percentage of the total responding. bTotal number of respondents from this group.
The pilots were then questioned pointedly whether automation had made them complacent, specifically in a way that detracted from their optimum performance. Fifty percent disagreed and four percent strongly disagreed. At the same time, twenty-nine percent agreed that automation had made them complacent. These results are listed in Table 14.

Table 14
Has automation made you complacent?

<table>
<thead>
<tr>
<th>Group</th>
<th>n</th>
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</tbody>
</table>

Note. SD = strongly disagree; D = disagree; N = neutral; A = agree; SA = strongly agree. aN is the number of respondents answering this category and the respective percentage of the total responding. bTotal number of respondents from this group.

This concluded the questions designed to facilitate the research hypothesis. The remaining questions were asked to help determine the overall feeling that the pilots have towards the trends in automation design and implementation.

Future implementation. There was a significant difference between the responses of the pilots from American
and Delta when asked if future implementation of automation into the cockpit would create a more stressful and higher workload environment. There was similar disagreement however, with 53% of American and 55% of Delta disagreeing.

The last question produced 52% disagreement when asked about the future roles that automation would play in cockpit design and pilot interaction. The question was geared towards the future use of automation which would shift the pilots role from one of controller to one of monitor. The comments from the pilots suggested that the lessons learned from the automated systems and the difficulties encountered will help designers and operators to preclude this shift in roles and maybe prevent future aircraft incidents and accidents. One pilot stated "that the inability to disconnect the automated system on the Airbus Industrie aircraft which lead to the total loss of aircraft and crew" was a perfect example of the operational application of the learned errors of automation. Questions #15 and #16 are not tabulated.
CHAPTER IV

Findings, Conclusions and Recommendations

Findings

There were one hundred fifty pilots selected to participate in this study. American Airlines had a 65.3% return rate while Delta Air Lines had 69.3%. This presented sufficient data to conduct the analysis and thus the data was equally representative of the carriers. The paragraphs that follow will highlight the findings of this investigation.

1. There was a significant difference in the years experience between the carriers, and between the captains and first officers of Delta Air Lines. The data suggest that the pilots of American have significantly more experience than those of Delta at the LAX hub. Additionally, the captains of Delta have significantly more experience than the first officers. Normally, the captains should have more years in the cockpit than the first officers. However, since there was a significant difference between both carriers, it appears that the pilot population in the first officer position at Delta is much less experienced than the rest of the sample. It will be important to be particularly alert to this factor while analyzing the remaining questions to determine if these first officers answer in a significantly different manner.
2. The initial questions determined that there was general agreement about how many systems were automated and that automated functions were utilized the majority of the time. There was majority agreement among the pilots that there is not too much automation. Their comments suggested that there is a choice with the amount of automation a pilot wishes to use. Given a choice, it is logical to expect their decision to balance on the side of safety. Hence, if an automated task presents a situation that may be unsafe, then the pilot will likely choose to perform that task manually to avoid the conflict. To determine if this were the case, the next step was to question whether the general utilization of automation and the procedures necessary for its implementation created any situations which may reduce safety.

3. There was slightly higher disagreement among American pilots when asked if automation had created an unsafe environment. 53% of the Delta first officers agreed and strongly agreed that automation had created an unsafe environment. This is the first indication where this particular group differed significantly from the rest of the sample. The majority of the comments suggested that if the automation were to create a situation that may jeopardize safety, the pilot was apt to discontinue its use. This was confirmed by the results of question #13 which asked specifically if manual backup had to be utilized. Recalling the fact that there was a significant difference between the
years experience of the two carriers, the data suggest that those with less time in the cockpit are prone to feel less safe than those with more. This is certainly a logical expectation and may be the sole reason for the belief that an unsafe environment had been created. This is compounded by the fact that Delta’s pilot force is very junior in the first officer position at the LAX hub.

4. The questions regarding the specific use of automated equipment produced similar results as the general questions. The answers of the pilots of Delta were significantly different than those of American when asked if the FMC impacted their outside scan. It is interesting to note that the captains of Delta felt the FMC did negatively impact their outside scan. One would have expected the first officers to complain about the requirements of automation keeping them inside the cockpit too much. None of the pilots felt the requirements were too time consuming though, during the critical phases of flight. They also were adamant in their faith in the TCAS system and its overall effectiveness.

5. There were disparate answers about the proficiency level maintained on these automated cockpits. Inferring from the comments, it appears that there are those that do and those that don’t remain proficient and by all indications thus far, by choice rather than design. Additionally, the pilots were split again on the question of increased workload with more Delta pilots indicating the
load was increased. This again may be due to the lesser experience level these pilots have. The majority of all pilots felt that they were at minimum proficient enough to perform manual tasks required during emergencies.

6. A majority agreement was found among both carriers indicating that the pilots felt automation induced complacency on the flight deck. The majority disagreed however, when asked if they had been complacent specifically in a way that detracted from their optimum performance. This disparity may be due to the lack of comfort with the automated environment for the majority.

Conclusions

Throughout this study a majority of the respondents supported automation, its usage and held the beliefs that the current environment implementing automation is a safe and manageable one. The minority who supported the belief that automation induces complacency, lack of proficiency or an unsafe environment, primarily responded from a position of lesser experience. This was not always the case, but was supported generally throughout. Hence, the hypothesis was supported since the attitudes and beliefs of the pilots from the two carriers indicated that automation is not a detriment to safety the majority of the time. The rejection of the null hypothesis also supports this conclusion since it helped to quantify the differences of opinion to those of the pilots with less experience.
Recommendations

Aviation has historically been very dynamic and it continues to be such, as well do the advances in automated equipment and their operational implementation. This study was just one of many in the ongoing analysis of the pilot-automation interface and the results can only suggest that more work need be undertaken. This fact is accentuated by the most recent presentation of incidents and accidents in the January 30, 1995 issue of Aviation Week & Space Technology. In this issue, numerous examples of accidents are documented describing the probable cause to be automation related with specific citations of pilot interface problems. One factor was continually dominant in these articles and was also prevalent in this study. This factor was that more problems are encountered, either perceptually or actually, the less experience the pilot has.

Immediately, it would appear that increasing the pilots proficiency and experience with the automated equipment will help alleviate many of the perception problems discovered in this study. The author’s experience with new equipment and procedures followed a similar pattern as a Naval Aviator. The more initial training received, the more relaxed and proficient one becomes. Many of the commercial airline training programs provide limited experience with the automated systems in simulated sessions due to operational and simulator commitments. If these sessions were to be increased initially, alleviation of some of these problems
may be realized. At the very least, additional training and simulator sessions should be provided for those who feel less comfortable and less proficient with the extensive modes of automation. The professional pilot should always admit shortcomings and seek ways to alleviate them.
REFERENCES


APPENDIX A

SUMMARY OF CHI-SQUARE
Summary of the chi-square

<table>
<thead>
<tr>
<th>Question #</th>
<th>Comparison</th>
<th>Chi square</th>
<th>Significant</th>
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*p < .05.
### Summary of the chi-square

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*p < .05.
October 20, 1994

William Woodrow Clark
4649 Pomona Street
Ventura, CA 93003
(805) 639-0219

American Airlines Flight Admin
P.O. Box 92246
World Way Postal Center (LAX)
Los Angeles, CA 90009

Dear Sir or Madam,

I would like to take this opportunity to thank you for your time and efforts with this important endeavor. I am a full-time student with Embry-Riddle Aeronautical University for the degree of Master of Aeronautical Science. This survey is being conducted to fulfill the requirements for my Graduate Thesis. Your participation is crucial in order for the research to be effective and applicable.

Enclosed you will find a questionnaire which requests specific information regarding the working environment of your particular cockpit. This questionnaire is being used to determine the effect increased automation has on pilot performance. The answers to these questions will be strictly guarded with no reference made to the pilot responding. Please indicate your choice by circling the appropriate response. Complete confidentiality will be maintained.

This study is a continuation of the numerous endeavors in this field. This issue has tremendous significance in terms of safety and the future utilization of automation and manual piloting skills. Proper choices for design and operational implementation can only be made from a strong position of knowledge.

You will find the questionnaire straight forward and easily completed. I applaud your professionalism for the desire to enhance the knowledge of safety issues in the aviation community. Please respond within (2 weeks) and return the questionnaire in the envelope provided. This questionnaire has been approved for distribution. If you have any questions regarding the validity of this questionnaire, please contact Captain Jim Keller, Chief Pilot, American Airlines LAX office.

Thank you again for your active participation.

Sincerely,

William Woodrow Clark (Woodie)
Lieutenant USNR-R
Naval Aviator

enclosures
October 17, 1994

Delta Air Lines, Inc.
(LAX)
Los Angeles, CA 90009

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Sincerely,

William Woodrow Clark (Woodie)
Lieutenant USNR-R
Naval Aviator

enclosures
Questionnaire

1. Are you a Captain or First Officer?
   a. Captain  b. First Officer

2. How many years experience do you have in this cockpit?
   a. < 1  b. 1-2  c. 3-4  d. 5-6  e. >6

3. What percentage of flying skills do you think are automated?
   a. < 25  b. 25-50  c. 51-75  d. 76-90  e. >90

4. What percentage of time do you utilize automated systems vice manual piloting skills, to include computations, switch selection, etc.?
   a. <25  b. 25-50  c. 51-75  d. 76-90  e. >90

5. Do you think that too many systems, procedures or tasks are automated?
   a. strongly disagree  c. neutral  d. agree  e. strongly disagree

6. Does the flight management computer keep you inside the cockpit too much, particularly during the low altitude phases of flight during higher traffic volume?
   a. strongly disagree  c. neutral  d. agree  e. strongly disagree

7. Are your manual flying skills deteriorating due to the extensive use of automation?
   a. strongly disagree  c. neutral  d. agree  e. strongly disagree

8. Are automation requirements too time consuming during the critical approach and landing phase?
   a. strongly disagree  c. neutral  d. agree  e. strongly disagree

9. Does automation increase your workload?
   a. strongly disagree  c. neutral  d. agree  e. strongly disagree

10. Do you believe that extensive use of automation may induce complacency on the flight deck?
    a. strongly disagree  c. neutral  d. agree  e. strongly disagree
11. Has automation made you complacent in a way that detracted from your optimal performance?
   a. strongly disagree  b. disagree  c. neutral  d. agree  e. strongly agree

12. Has any form of automation created an unsafe environment in the cockpit?
   a. strongly disagree  b. disagree  c. neutral  d. agree  e. strongly agree

13. Has any specific task performed by automation created a situation that required utilization of manual backup?
   a. strongly disagree  b. disagree  c. neutral  d. agree  e. strongly agree

14. Do you fly the aircraft manually with sufficient frequency to maintain your skills at an acceptable level, particularly with the ability to perform required functions off-line during an emergency?
   a. strongly disagree  b. disagree  c. neutral  d. agree  e. strongly agree

15. Has the cockpit crew grown dependent upon the use of TCAS to the detriment of a good lookout doctrine?
   a. strongly disagree  b. disagree  c. neutral  d. agree  e. strongly agree

16. If you agree with question #15, has this dependency created an environment that may lead to a mishap?
   a. strongly disagree  b. disagree  c. neutral  d. agree  e. strongly agree

17. Do you believe that continued implementation of automation will create a future cockpit environment that is more stressful or has a higher workload?
   a. strongly disagree  b. disagree  c. neutral  d. agree  e. strongly agree

18. Will this same future implementation shift the role of the pilot from one of controller to one of monitor, to the detriment of the safe conduct of the flight?
   a. strongly disagree  b. disagree  c. neutral  d. agree  e. strongly agree

Please feel free to comment on any question by #, or make any other comments you wish. Use the back of these sheets if desired.
APPENDIX D

SCHEDULE
1. Proposal approved .................. May 1994
2. Guidance Committee secured .... September 1994
3. Review of related literature ..... September 1994
4. Selection of sample ............... September 1994
5. Questionnaire delivered ........... October 1994
6. Follow-up actions .................. November 1994
7. Data Analysis ..................... December 1994
9. First draft ........................ February 1995
10. Final draft ........................ March 1995