Preliminary Identification of Factors Causing Pilots To Disconnect the Flight Management Systems in Glass Cockpits

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Research in cockpit automation has indicated that pilots sometimes have difficulty understanding and operating cockpit automation systems. Problems with operating automated systems or the need to reprogram systems has the potential to keep pilots looking inside the cockpit during critical phases of flight when, in fact, they should be looking outside the cockpit. An alternative to reprogramming the automation, particularly the flight management system, is either to turn the automation completely off or to reduce the level of automation to the basic autopilot. Observations indicate, however, that pilots often do not turn off the automation when lengthy reprogramming is required. The identification of specific conditions under which pilots disconnect cockpit automation was made to determine whether they disconnect it when it is appropriate to do so. Examination and analysis of a field study of automation use from a major air carrier data base containing observational activities of crews were conducted. Second, the National Aeronautics and Space Administration's Aviation Safety Reporting System data base was queried. Third, pilots from major air carriers were surveyed to ascertain their decisions to disconnect the automated systems during flight and the circumstances affecting those decisions. Several common factors were found to affect pilots' decisions to disconnect automated systems. These multiple factors were pilot experience, work load, rapid air traffic control–issued changes, automation performance, weather, equipment failures, and congested airspace. These factors support prior automation research findings by others investigating various automation issues.

Automation-assisted flight has been used routinely in civil air transport since the end of World War II (*1*). Recently, fly-by-wire aircraft have been introduced with advanced control systems, flight management computers to aid navigation and flight path, and automated subsystem management computers that alleviate the crew of all routine subsystem management tasks (*1*).

Though modern aircraft may be easier to fly than the less advanced aircraft of the past, pilots must keep track of much more information than ever before. Pilots must know where they are and where their destination is located and be aware of environmental threats such as weather, terrain, and other aircraft (*2*). In addition, they must know the state of their aircraft, its systems, and consumables. The nature of most of the information they must monitor and control is dynamic and unpredictable.

Originally, automation was designed and introduced into the cockpit to aid pilots in performing information gathering, management, and control tasks (*1*). Automation of the flight deck was seen also as a way to drive human error out of the cockpit or "automate human error out of the system" (*3*).

The idea of automating as much as possible was very popular in the 1970s and early 1980s (*1*). Increased safety and pilot work load reduction were the expected benefits of automation in the cockpit (*1*). However, in the mid-1970s automation was beginning to be viewed as a possible source of problems in accidents and incidents in the aviation industry (*1,4*). The rapid introduction of automated technologies into the cockpit resulted in critical analyses from the aviation community regarding the use of automation. This introduction of automation was made possible by the increasing sophistication of microprocessor technology and display systems (*5*).

The benefits and pitfalls of cockpit automation have been under analysis for the last two decades. From the earliest investigations of cockpit automation, skepticism was expressed concerning the overall value of automation. One of the first published articles by Wiener and Curry (*3*) asks whether human error can truly be eliminated through automation. The temptation to design out human error, thereby reducing costly accidents and incidents, was nearly irresistible to engineers. Some researchers, however, had begun to ask whether automation had passed its ideal point. By the late 1970s, the U.S. government led by Congress directed the National Aeronautics and Space Administration (NASA) to examine human factors in cockpit automation (*4*).

PURPOSE

The purposes of the research presented here are to identify the conditions under which pilots disconnect cockpit automation and to determine whether they disconnect it when it is appropriate to do so. The research was conducted in three major segments. The first involved a field study of automation use from a major air carrier. The second involved analyzing the NASA's Aviation Safety Reporting System (ASRS) data base. The third and final segment involved conducting selected interviews followed by surveys with pilots from various air carriers.

BENEFITS OF AUTOMATION

Wiener (*6*) has also outlined eight benefits or reasons behind the use of cockpit automation, three of which are mentioned below.

Work load reduction is considered a primary incentive for the use of automated devices in cockpits. Work load reduction is viewed as a necessity for a variety of reasons, including the assumption that pilots prefer to be relieved of routine manual control and mental arithmetic. The alleviation of routine tasks is supposed to allow pilots time to oversee the flight and to be effective in emergencies. Another reason for work load reduction is to increase the time pilots

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can spend scanning or looking out the cockpit, rather than performing tasks that require looking inside the cockpit.

However, a research study of 200 Boeing 757 pilots conducted by NASA indicates that automation actually increased work load (*7*). Another reason for work load reduction is the change from three-pilot to two-pilot crews. Researchers report that the designers should be aware that each automated device creates its own scanning demand. Automation may not be increasing the time spent looking out the cockpit.

Increased flight precision and maneuvers created a need for conserving valuable and increasingly busy airspace. The economical use of airspace will require aircraft to travel closer together than ever before. Precise flight paths and maneuvers will allow for precision navigation; lateral, vertical, and longitudinal speed; and effective spacing of aircraft arrivals and departures.

Display flexibility has permitted designers to display information in many innovative ways. Software-generated displays allow pilots to configure their displays in a flexible, personalized manner. The problem is that the amount of information displayed may become overwhelming.

AUTOMATION PROBLEMS

Many problems are cited as a result of automation. Recently, it has been reported that pilots and researchers believe that the benefits of automation are debatable (*8*). Mecham reports that the idea that automation was introduced into the cockpit without adequate scientific study or empirical data is becoming increasingly popular (*8*). It has also been claimed that inappropriately designed automated systems are placing aviation safety at risk (*9*). Several other issues have been raised regarding automation and its potential problems.

Work Load

Although work load reduction is seen as a major benefit of automation in the cockpit, some researchers and pilots report that work load is not reduced in the busiest and most critical flight segments, such as during climb or descent into terminal areas (*10*). These flight segments become increasingly intense when air traffic control (ATC) issues changes. Some pilots report that they have never been busier than in glass cockpits even though automation promised to reduce work load (*10*). Reported research findings, however, do not clearly support either work load reduction or work load increase (*11*). In a recent study, pilots disagreed about the issue of work load (*12*). Half of the pilots surveyed reported concerns that automation actually increased work load. The respondents believed that work load was increased during flight phases that already have high work load and decreased work load in flight phases that have low work load (*12*). Crews also reported that in times of high work load, they turned the automation off and returned to manual modes of flight because they did not have time to reprogram and take advantage of the automation. This situation has been called the paradox of automation (*12*).

Loss of Manual Flying Skills

Pilots are reported to be concerned about overreliance on automation leading to a deterioration of basic flying skills (*13,14*). In one study of 200 Boeing pilots, nearly half reported that they were concerned about the possible loss of manual aviation skills because of too much automation (*7*). The study also indicated that 90 percent of the pilots reported that they hand-fly part of every trip to maintain their flying skills. Similarly, a study of pilot attitudes toward cockpit automation found that pilots are concerned about the loss of flying skills (*15*).

Along with the possible loss of flying skills due to overreliance on automation, some pilots report concerns about the reluctance to take over from an automated system. This reluctance often continues even when there is overwhelming evidence that something is wrong. The nature of these expressed concerns are self-assessments of personal performance and, therefore, cannot be relied upon as objective measures of actual flight performance in the operational environment (*11*).

Feelings of Disassociation from the Aircraft

The current generation of advanced cockpits has extensive computer processing of data from aircraft subsystems before presentation to the pilot (*15*). This processing has the capability of divorcing the crew from the raw data and, consequently, the state of the aircraft. In a study conducted by Wiener (*6*), pilots reported that they sometimes feel they are "along for the ride." Pilots also state that the problem is not insufficient work load but the feeling that they are "out of the loop." These statements refer to feelings that pilots report when the automation takes over and makes decisions without them. This feeling of disassociation has reportedly caused pilots and crews to "program" their way out of a problem rather than to deactivate the automation and fly the aircraft manually (*6*).

Situation Awareness

This feeling seems to be related to the frequently used term "situation awareness." Sarter and Woods (*9*) define situation awareness as "all knowledge that is accessible and can be integrated into a coherent picture, when required, to assess and cope with a situation." The loss of situation awareness can be potentially disastrous in the cockpit.

One common factor that seems to contribute to the loss of situation awareness is weak feedback from the automation displays and interfaces (*16*). Other clues that indicate a loss of situation awareness are failures to meet targets, undocumented procedures, departure from standard operating procedures, violation of minimums and limitations, no one flying the aircraft, and no one looking out the window (*17*).

Trustworthiness

Trustworthiness of automation is a problem that has been identified in automation research. Human trust in automation has been described by Riley (*2*) as the operator's subjective estimate of the probability that the next decision or action made by the automation will be correct. The problem of trustworthiness revolves around automation errors caused by system failures. The unreliability of an automated system can result in a system that is more costly to use, increases work load, and decreases safety. In general, however, automated systems are highly reliable (*4*).

Inappropriate Feedback and Interaction

Automation is often powerful enough to take over control of many complex tasks, but it is not powerful enough to handle the variety of abnormalities that can arise in the flight environment (*18*). The problem is that under normal operating conditions automated systems function in a manner that keeps human operators isolated from the moment-to-moment activities of the aircraft and controls. Therefore, when critical situations arise that cannot be handled by automation, the crew must be able to step in and recover the situation. Norman (*18*) suggests that problems are inappropriately blamed on automation being too powerful when, in fact, the real problem is that automation is not powerful enough.

Computer Changes

Reprogramming flight management computers during flight has been cited as a serious cause for concern. The results of a 3-year NASA study report that pilots are concerned about the tendency for crews to spend too much time looking heads-down or inside the cockpit while reprogramming flight computers (*7*). During the most critical phases of flight, pilots report excessive work load with the slightest change in their flight path (*10*). Pilots have also reported that it takes the undivided attention of one pilot to reprogram the computers (*7*). Pilots also claim that computer-driven cockpits demand a high degree of proficiency and are unforgiving to inexperienced pilots (*19*). Many of the computer devices used in cockpits will accept entries only in a certain format. Hughes (*19*) mentions that pilots can slip 10 mi behind the aircraft in their thinking in a very short time.

Pilot Interface

With increasing automation, pilots can become monitors of automated systems rather than aircraft controllers (*20*). The use of automated systems mandates that the interface be designed to take optimum advantage of human capabilities and the object controlled. The combination of manual and automatic control must be flexible (*21*). A review of research by Bergeron and Hinton (*20*) indicates several guidelines for good pilot interfaces with aircraft automation: aircraft status information and feedback should be simple, natural, and precise; flight-critical information should be continuous; control consoles should minimize the number of inputs; and routine and noncritical operations should be automated.

Training

Training issues are also shown to be potential sources of problems. There is a temptation for cost-conscious management to reduce training costs because they see the pilots' job as simpler with the aid of automated devices (*22*). Tullo (*22*) states that the opposite should in fact be happening. Researchers have found that pilots of glass cockpit aircraft indicate that they could use more training on how to use the numerous features of the complex autoflight and flight management systems (FMS) in glass cockpits (*12*). Another study conducted on pilot training for advanced cockpits found that automation has not reduced training needs (*14*). Pilot training should continue to emphasize system knowledge and simulator training but also additional education in the critical concepts of flight deck management (*22*). The Airbus Industrie subsidiary Aeroformation that directs Airbus training enforces the idea that crews need to maintain basic flying skills despite very high levels of automation (*23*).

RESEARCH ON AUTOMATION DISCONNECTS

Regardless of the problems associated with automation, there has been general acceptance of the use of automated systems on the flight deck (*11*). Automation also has been well received by pilots. The findings of several surveys and studies indicate that most pilots prefer to fly technologically advanced aircraft rather than the older, less sophisticated types (*11*). These findings lead to the conclusion that automation will continue to be used in cockpits and will probably increase in sophistication. Despite the increasing interest in cockpit automation, few empirical data are available about automated cockpit systems (*16*). Therefore, further detailed research into specific problems facing automation in the cockpit is clearly needed. The following research examines just one of the numerous problems associated with automation use.

Previous research indicates that pilots sometimes have difficulty understanding and operating cockpit automation systems (*16*). Problems with operating the system or the need to reprogram it have the potential to keep pilots flying heads-down, that is, looking inside the cockpit rather than flying heads-up, or looking outside the cockpit. An alternative to reprogramming the automation, particularly the FMS, is either to turn the automation completely off or to reduce the level of automation to the basic autopilot. Casual observations indicate, however, that pilots often do not turn the automation off when lengthy reprogramming is required (*24*).

The purposes of the research presented here are to identify the specific conditions and factors under which pilots disconnect cockpit automation and to determine whether they disconnect it when it is appropriate to do so. Three different techniques were used to investigate automation disconnects. The first segment of research involved a field study of automation use from a major air carrier. The second involved analyzing the data base available through NASA-ASRS. The third involved selected interviews followed by surveys with pilots from various air carriers.

FIELD STUDY OF AUTOMATION USE

The purpose of using this data base was to identify the conditions present when pilots disconnect the FMS and assess the appropriateness of their actions. The data base consisted of in-flight data gathered from 20 three-day trips with airline crews from a major air carrier, totaling 200 legs. The individual behaviors of the captains and first officers were recorded in the form of activity codes. The activity codes were collected every 7.5 sec. Data collection of each leg of a trip began from the takeoff roll of the aircraft to cruise altitude and then from top of descent to the arrival gate. Therefore, each leg had four segments: climb under and over 3050 m (10,000 ft) and descent under and over 3050 m (10,000 ft). The activity codes include behaviors such as hand-flying the aircraft while the autopilot was disengaged, looking out the window, manipulating the FMS, looking inside the cockpit, speaking to ATC, engaging the autopilot, and manipulating control wheel steering. The codes represent four types of activities: eyes, hands, communication, and global. The codes also represented only observable behaviors. The thought processes behind pilot responses could only be inferred. Therefore, any theorized pilot reasoning behind the activities codes was purely speculative.

Descriptive Categories

Approximately 40 out of the total 200 legs were identified as containing instances where pilots connected and disconnected the automation more than once during a flight. These unusual occurrences of engaging and disengaging automation multiple times in one leg accounted for roughly 20 percent of the total legs. These instances were then analyzed individually and inferences were made to categorize them into nine groups. The activities surrounding these automation codes were also investigated to identify any factors surrounding these disconnects.

Categorizing the 40 legs yielded 57 instances of automation disconnects. The 57 instances were individually analyzed and categorized. The results of categorizing the data led to the formation of nine descriptive groups. Figure 1 shows the nine descriptive categories of automation disconnect and their corresponding percentage of disconnects.

Control Wheel Steering

The control wheel steering (CWS) manipulation category refers to the pilot's use of CWS as a lower level of autopilot control. In these instances, the pilot only reduced the level of automation to CWS and then returned to the basic autopilot function rather than completely disconnecting all automation. This category accounts for 18 percent of all instances. Inclusion of an incident in this category was determined by the presence of a CWS code followed shortly by an autopilot code.

Unexpected Automation Performance

The category of unexpected automation performance of the describes instances in which pilots appeared to be surprised by the performance of the automation. This category accounts for roughly 18 percent of disconnects. This category includes MCP selection errors or programming errors. Included in this group are incidents of multiple MCP activity codes occurring before, during, and after automation disconnects. That the automation is not performing as expected or desired can only be inferred by the surrounding activity codes. The reasons behind the unexpected activity codes also can only be inferred because of the nature of this observational data base. It is impossible to determine whether the automation is responding in a surprising manner to the pilot's inputs because of correct or incorrect programming selections, incorrect data input, equipment failures, or inadequate system knowledge. The multiple reprogramming attempts by pilots are also plausible explanations for these codes.

Work Load

The category of work load was responsible for nearly 14 percent of automation disconnects. Inclusion of an instance in this category was determined by numerous activity codes in relatively small amounts of time surrounding the disconnect. An example of an incident that would be included in this category is multiple ATC calls occurring with numerous MCP inputs at a high–work load phase of flight at a particularly busy airport.

Equipment Failure

Equipment failures were responsible for nearly 11 percent of automation disconnects. This category includes any malfunction of any automated flight system, including the autopilot, autothrottle, or automated navigation systems. Inclusion of an incident in this category was determined by notes or citations of equipment failures made by the observer or by inference from the activity codes surrounding the automation disconnect.

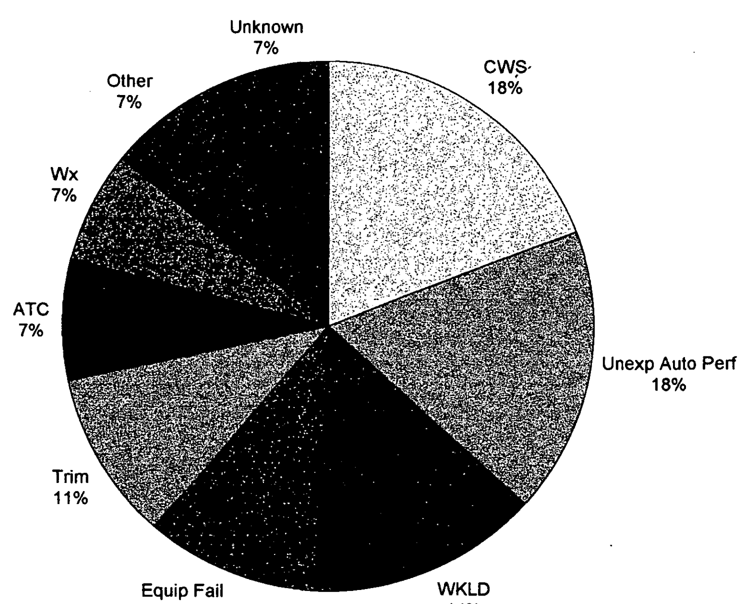

FIGURE 1 Percentages of automation disconnects from air carrier data base.

Trimming

Trimming the aircraft accounted for approximately 11 percent of the disconnect occurrences. Instances were assumed to belong to this category if rudder activity codes closely followed the automation disconnect.

ATC

The ATC category of automation disconnects includes altitude deviation, speed corrections, and any ATC-related issue or change made to the pilot by ATC. This category accounts for roughly 7 percent of all automation disconnects. Inclusion in this category was determined by ATC activity codes occurring before the automation disconnect and by inferences drawn from surrounding activities.

Weather

Weather-related disconnects were responsible for 7 percent of occurrences. Instances of automation disconnects were placed in this category when pilots encountered weather conditions resulting in flight through clouds or notification of impending flight through problematic weather conditions. Typically, this category includes instances when pilots appeared to be navigating around weather.

Other

The "other" category accounts for 7 percent of disconnects. This category includes disconnects that cannot be placed into any of the other categories and occur only once. An example is an autothrottle disconnect that occurred when an aircraft needed to wait on the runway after preparing to depart because of delayed landings.

Unknown

The "unknown" category is responsible for 7 percent of all incidents. A disconnect was included in this category if its cause could not be determined. The activity codes surrounding the disconnect did not supply any information that could lead to categorizing the incident into any of the other eight descriptive categories.

Flight Segment

An analysis of automation disconnects occurring in various flight segments was conducted for all incidents. The flight segment containing the highest percentage of disconnects was the descent above 3050 m (10,000 ft). Approximately 35 percent of all incidents fell into this category. The flight segments of climb under and above 3050 m (10,000 ft) represented 23 and 26 percent of all disconnects, respectively. The segment of descent under 3050 m (10,000 ft) contained only 15 percent of automation disconnects.

The analysis of this data base has permitted the identification of incidents in which automation was engaged and disengaged more than once per leg. Approximately 40 legs, or 20 percent, were found to include disconnects. The nature of this observational data base allows only the categorization of automation disconnects according to descriptive categories, as well as flight segment. The reasoning behind pilot motives to disconnect or reconnect the automation was not explicitly made known through the data collection techniques. Inferences, however, have been made regarding reasons for the disconnects and reconnects.

NASA-ASRS DATA BASE

The second segment of this research involved analyzing the data base available through NASA-ASRS. Searches and analyses were conducted on all automation disconnect reports for all aircraft types as well as on specific aircraft type reports. This was necessary because of the data base aircraft type de-identification format. The following types of aircraft were queried individually: A-320, Boeing 747-400, and Boeing 757/767. The remainder of this discussion will focus on the searches and analyses from the requests of all aircraft type and Boeing 757/767 disconnect reports.

Search Request on All Automation Disconnect Reports

The results of this search produced a list of automation-related incidents referencing disconnects for all aircraft types. A total of 300 reports was made available from the NASA-ASRS office. The reports were narrations of incidents and accidents related to the disconnection of automated systems.

An analysis of these reports was conducted on the aircraft falling into the following weight classes: large transport [68 100–136 200 kg (150,001–300,000 lb)], heavy/large transport [more than 136 200 kg (300,000 lb)], and wide-body [more than 136 200 kg (300,000 lb)]. From these weight classes, 57 automation disconnects were found relevant to this research. The analysis of these remaining reports then allowed grouping of the incidents into categories. Seven categories emerged from the analyses of these reports. Figure 2 shows the categories and percentages of automation disconnect from the NASA-ASRS search.

In each of the three weight categories, equipment failures accounted for approximately 50 percent of all automation disconnect incidents. Across all three weight categories, weather and turbulence was the second largest category and was responsible for roughly 22 percent of the incidents. ATC-related issues, such as altitude deviations or changes, accounted for 9 percent of all disconnects for the three weight classes. The Other category was responsible for 11 percent of all incidents. The Unknown category accounted for 4 percent of disconnects. The remaining categories—trimming an aircraft and pilot selection errors—each accounted for 2 percent of disconnects.

Search Request on Boeing 757/767-Type Reports

The search request conducted on Boeing 757/767 was referenced by key words, such as two engines, advanced cockpit, 68 100–136 200 kg (150,000 to 300,000 lb), and more than 136 200 kg (300,000 lb). This search request generated 300 Boeing 757/767 type reports.

The analysis of these reports found 22 incidents that contained references to automation disconnects. The reports were classified into six categories, as shown in Figure 3. The largest category was equipment failures with 31 percent of all disconnects. Selection and programming errors, the second largest category, contained 18 percent of reported disconnects. The categories of ATC and approach issued changes, Other, and Unknown each accounted for 14 percent of total automation disconnects. The smallest category, accounting for 9 percent, consisted of weather- and trimming-related disconnects.

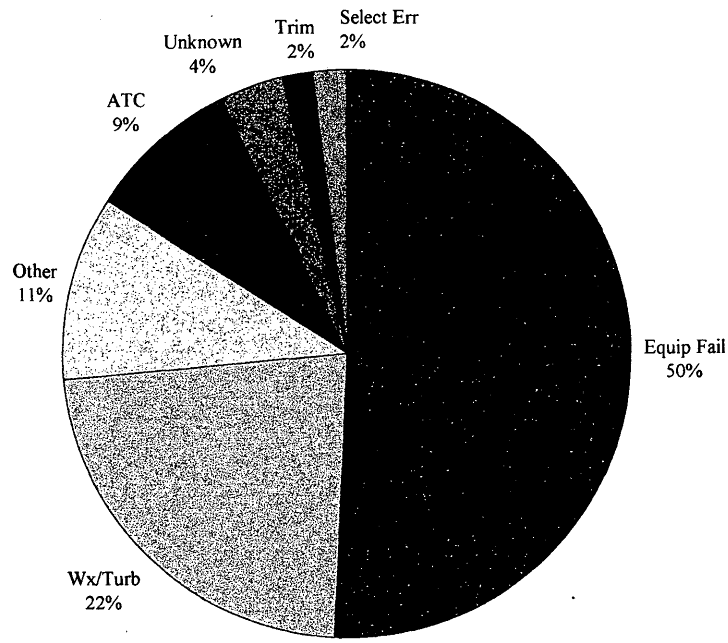

FIGURE 2 Percentages of automation disconnects from NASA-ASRS search of all reported automation disconnects.

INTERVIEWS AND SURVEYS

The third segment of research involved selected interviews followed by surveys with pilots from various air carriers. The interviews were used to develop the survey questions and format. The survey was used to question pilots directly about their decision to disconnect the automated systems during flight, the circumstances surrounding the disconnects, and the factors and parameters affecting their decision to disconnect the automation. The interviews and surveys also served to obtain pilots' attitudes and opinions concerning cockpit automation. Surveys were distributed to three major air carriers: 30 to Air Carrier X, 25 to Air Carrier Y, and 15 to Air Carrier Z. The survey distribution parameters were limited to 757/767 captains and first officers.

Demographic Information

The survey yielded 42 respondents. Seventy percent of the respondents held the position of captain on their current aircraft. The mean total flight hours of the pilots was 13,700, and mean months on the Boeing 757/767 was 36. The mean age of the pilots was 48.

Experience

Ninety-five percent of respondents indicated that they disconnect automation to maintain their flying skills. Roughly 40 percent indicated that they disconnect automation and hand-fly their aircraft at least once every leg. When asked if they used automated systems more, less, or no differently as they have become more experienced in flying their current aircraft, 7 percent said they used them less, and 43 and 50 percent said they used them the same or more, respectively. The mean number of hours pilots felt it took them to feel very comfortable with their current aircraft's automation was 160. Fifteen percent of pilots responded that their flight time to comfort was in excess of 500 hr. Ten percent of pilots responded that they use memory aids to help them with the automation in their aircraft. Of the 10 percent who used memory aids, half were first officers with a maximum of 11,000 hr.

Training

When asked whether they had received enough initial training on the automation in their cockpits, 17 percent of the pilots indicated that they did not feel they had been given enough training. Of these 17 percent, 30 percent were first officers with fewer than 9,000 total flight hr. Similarly, 25 percent of pilots responded that when they changed to their current aircraft, they found the automation difficult to use. Eighty percent of these pilots were over the age of 50 and all were captains.

Reliability

Fifty-five percent of pilots indicated that they had disconnected the autopilot or autothrottles because they were concerned about the reliability of the automation. Seventy-four percent of pilots responded that they had experienced failures of autopilot components on their aircraft.

Work Load and Automation Management

When pilots were asked if they disconnect the automation in high work load environments, 67 percent answered that they disconnect when the work load is high. Sixty-seven percent responded that it takes more time to program the autopilot in high work load phases of flight than it does to disconnect the automation and hand-fly the aircraft. When asked if they had ever programmed or reprogrammed the automation when in retrospect they should have dis-

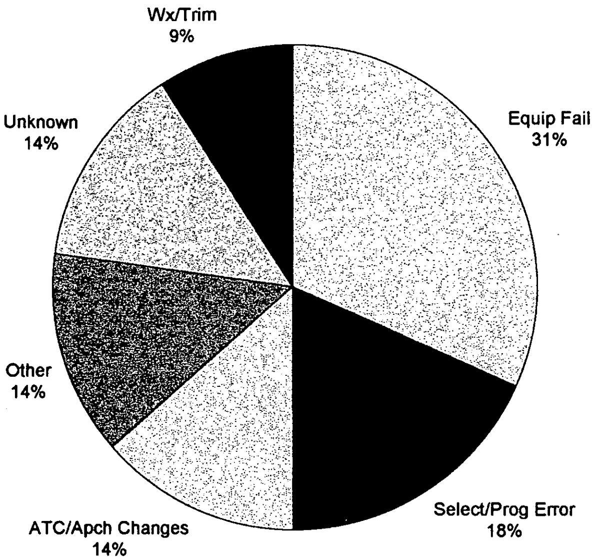

FIGURE 3 Percentages of automation disconnects from NASA-ASRS search of Boeing 757/767-type reports.

connected the automation and hand-flown the aircraft, 79 percent responded that they had. Ninety percent of pilots claimed that they made an error when programming the FMS, MCP, and so forth and had to disconnect either the autopilot or autothrottles. Twenty-four percent of pilots also indicated that they have had to disconnect the automation because they did not understand the automation, error message, or modes. Of these pilots, half had less than 12 months on the aircraft.

Approach and En Route

Pilots responded that several factors influence their decision to disconnect automation during approach. Figure 4 shows these factors in the approach and en route phases of flight. Multiple ATC changes were the most frequently cited factor that affected pilots' decisions to disconnect automation during approach. This factor was cited by 31 percent of respondents. Work load was the second most frequent factor affecting automation disconnects. This factor accounted for approximately 26 percent of responses. Weather was cited by 24 percent of pilots as an important factor. Pilot experience with automation accounted for 19 percent of the factors affecting the decision to disconnect during approach.

When pilots were asked if they had ever had to disconnect automation during an approach and then had to reconnect, 55 percent claimed they had. When pilots were asked if there were any external factors that affected their decision to disconnect automation en route, several factors were cited (see Figure 4). Pilot experience with automation was the most commonly cited factor affecting the decision to disconnect en route. This factor accounted for approximately 31 percent of disconnects. Multiple ATC changes were the second most frequently cited factor—accounting for 27 percent—affecting pilots' decisions to disconnect. Weather and busy airspace were two other factors cited by pilots and accounted for 24 and 18 percent of factors affecting disconnects, respectively.

Other

When pilots were asked if they ever disconnect the automation to increase passenger comfort, 38 percent responded that they do disconnect for comfort. Thirty-six percent of respondents reported witnessing unusual autopilot procedures or techniques in other pilots. When asked if they had ever noticed any instances when other pilots should have disconnected the automation but did not, 57 percent responded they had.

CONCLUSIONS

This research used three techniques to identify the specific conditions under which pilots disconnect cockpit automation. These three approaches consisted of examining and analyzing a major air carrier data base containing observational data of pilot crew activities,

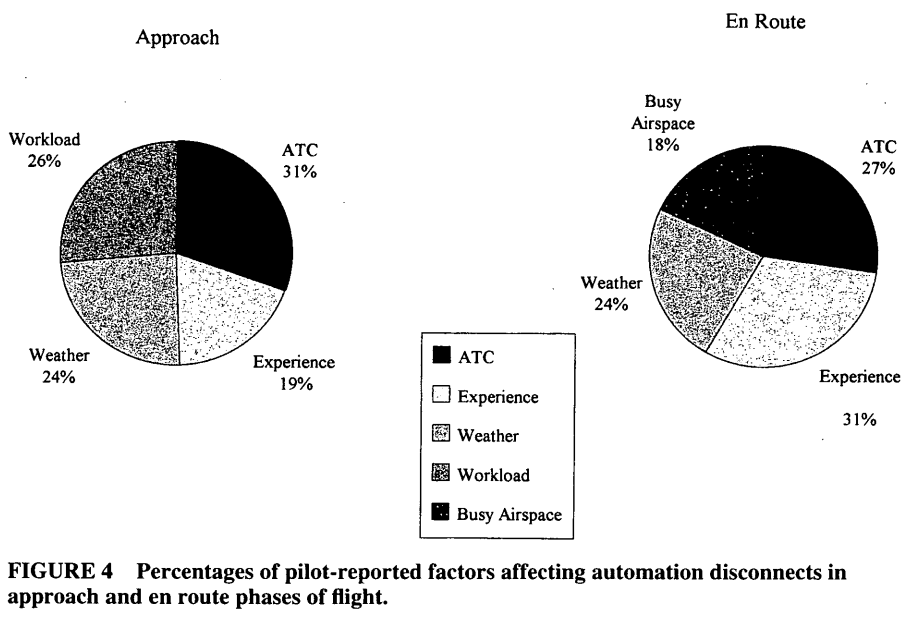

FIGURE 4 Percentages of pilot-reported factors affecting automation disconnects in approach and en route phases of flight.

querying and analyzing a variety of searches from the NASA-ASRS data base, and conducting selected interviews and surveys with pilots from major air carriers about their decisions to disconnect the automated systems.

These three research segments revealed multiple factors that influence pilots' decisions to disconnect automated systems. Pilot experience, work load, multiple and rapid ATC-issued changes, automation performance, weather, equipment failures, and busy airspace are factors that affect pilots' decisions to disconnect automation. The largest portion of automation disconnects was determined to occur in the descent above 3050 m (10,000 ft) flight segment. The surveys indicated several factors related to specific automation issues, including reliability, experience, training, and work load, which affect pilots' decisions to disconnect automation.

The findings support other research on various automation-related issues. For example, investigators have found that pilots report disconnecting automation once per trip to maintain their flying skills (*14,15*). Findings in this research also support those from Sarter and Woods (*16*) indicating that a large number of pilots on the Boeing 757 are surprised by the automation or do not understand all the modes and features of the FMS. These results also support prior research that had found that pilots disconnect automation during high work load phases of light (*12*).

This research focused on just one of many important automation-related issues. Because of the lack of empirical data on these issues, research investigating automation and pilots' use of automation needs to be continued.

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