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Automation in Aviation—Accident Analyses

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Table of Contents

List of Figures

List of Tables

Automation in Aviation—Accident Analyses

Accident Analyses

Given the wide diversity of automation and automation applications in aviation as well as the problems identified above, it is critical to understand the role of automation in accidents and incidents. A review of these automation-induced accidents is presented in this section.

Two extensive reviews in this area were those done by the Federal Aviation Administration (FAA) Human Factors Team and those performed under a National Aeronautics and Space Administration (NASA) contract as part of the Aviation Safety Reporting System (ASRS). The ASRS is a voluntary, confidential, and non-punitive database for flight crews and Air Traffic Control (ATC) (see Reynard, 1983). A short article in Air Safety Week (2001) provided a partial list of aviation accidents involving human errors related to automation. Other researchers have focused their analysis on factory automation; others on automation design, rather than on the events of the automation induced accident; others on basic human factors; and still others on surveys. Each of these approaches is reviewed in the following subsection.

FAA Human Factors Team Review

The FAA Human Factors Team Report (1996) analyzed both accident/incident reports and reports from the confidential NASA ASRS to identify major categories of problems with current flight deck designs. They concluded that automation was one of these problem categories. Specifically, "Incorrect settings accounted for 28 percent of all reports, and in three quarters of these it was a primary factor. Incorrect settings can be related to inadequate interface design, poor understanding of the system and genuine error. In terms of the incident/accident reports, it was found to be strongly related to monitoring and vigilance, where perhaps an unnoticed erroneous input resulted in more serious problems later. Improper use of systems occurred in 15 percent of reports and could result from poor understanding of systems and not using procedures correctly. Lack of mode awareness was identified as a factor in 6 percent of reports and was related to experience and inadequate knowledge of aircraft systems, as well as monitoring/vigilance and incorrect settings items. This factor was not as commonly occurring as perhaps might have been expected, perhaps because it is difficult to report what one is not aware of, when describing a situation for an accident/incident report."

Excerpts from the ASRS are presented below:

> "Needless to say, confusion was in abundance. There are just too many different functions that control airspeed and descent rates, all of which can control the altitude capture.
>
> My first priority was data entry rather than [Situational Awareness] SA.
>
> We missed the crossing altitude by 1000 feet. The captain was … busy trying to program the Flight Management Computer. … No one looks outside." (FAA Human Factors Team, 1996, p. 43).

A list of both aircraft incidents and accidents involving automation is presented in Table 1.

Table 1. ***Examples of Incidents and Accidents Involving the Human Factors Issues in the Flightdeck*** **(FAA Human Factors Team Report, 1996) and FAA's Lessons Learned from Civil Aviation Accidents**[1]

Date	Location	Airplane Type	Operator	Description
12/29/72	Miami	L-1011	Eastern Air Lines	Flight crewmembers became immersed in an apparently malfunctioning landing gear. Airplane was in control wheel steering mode. Altitude hold inadvertently disengaged by a light force on the control wheel. Altitude alert aural warning not heard by flight crew. Fatal crash.
7/31/73	Boston	DC-9-31	Delta Air Lines	Airplane landed short during an approach in fog. Flight crew was preoccupied with questionable information presented by the flight director. Fatal crash.
2/28/84	New York	DC-10-30	Scandinavian Airlines	Minor injuries. Complacency and over-reliance on automatic systems cited.
2/19/85	San Francisco	747SP	China Airlines	Loss of power on one engine during auto flight. Autopilot tried to compensate until control limits were reached. Captain disengaged autopilot. Airplane went into unusual attitude high-speed dive but was successfully recovered. Autopilot masked approaching onset of loss of control.
6/26/88	Habsheim	A320	Air France	Low, slow flyover at air show. Ran out of energy and flew into trees. Possible overconfidence in the envelope protection features of the A320. Fatal crash.
7/3/88	Gatwick	A320	Unknown	Programmed for three-degree flight path but inadvertently was in vertical speed mode and almost landed three miles short.
6/8/89	Boston	767	Unknown	On autopilot ILS approach, airplane overshot the localizer. Captain switched from approach to heading select mode to regain the localizer, disengaged the autopilot, and used the flight director. Since the glide slope had not been captured, the flight director was in vertical speed mode commanding a 1,800-foot per minute rate of descent. Alert from the ground proximity warning and tower resulted in a go-around from about 500 feet.
2/14/90	Bangalore	A320	Indian Airlines	Inappropriate use of open descent mode. Fatal crash.
6/90	San Diego	A320	Unknown	Pilot mistakenly set vertical speed of 3,000 feet per minute instead of 3.0-degree flight path angle. Error was caught but airplane descended well below profile and minimum descent altitude.

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[1] http://lessonslearned.faa.gov/

Date	Location	Airplane Type	Operator	Description
2/11/91	Moscow	A310	Interflug	Pilot intervention in autopilot-coupled go-around resulted in the autopilot commanding nose-up trim while the pilot was applying nose-down elevator. Autopilot disconnected when mode transitioned to altitude acquire mode - force disconnect not inhibited in this mode as it is in go-around mode. Airplane ended up badly out of trim and went through several extreme pitch oscillations before the flight crew regained control.
1/20/92	Strasbourg	A320	Air Inter	Evidence suggests flight crew inadvertently selected 3,300 feet per minute descent rate on approach instead of 3.3-degree flight path angle. Fatal crash.
9/13/93	Tahiti	747-400	Air France	Vertical Navigation (VNAV) approach with auto throttle engaged, autopilot disengaged. Upon reaching the published missed approach point, VNAV commanded a go-around and the auto throttle advanced power. After a delay, the flight crew manually reduced power to idle and held the thrust levers in the idle position. The airplane landed long and fast. Two seconds prior to touchdown the number one engine thrust lever advanced to nearly full forward thrust and remained there until the airplane stopped. Reverse thrust was obtained on the other engines. The spoilers were not deployed—the automatic system did not operate because the number one thrust lever was not at idle and the flight crew did not extend them manually. The flight crew lost directional control of the airplane as the speed decreased and the airplane went off the right side of the runway.
9/14/93	Warsaw	A320	Lufthansa	Wet runway, high tailwinds. After touchdown, the air/ground logic did not indicate the airplane was on the ground and delayed deployment of ground spoilers and reversers. Airplane overran runway. Two fatalities.
4/26/94	Nagoya	A300-600	China Airlines	Flight crew inadvertently activated the go-around switches on the throttle levers during a manually flown approach. This action engaged the auto throttles and put the flight guidance system in go-around mode. Flight crew disconnected the auto throttles but excess power caused divergence above the glide slope. Flight crew attempted to stay on glide slope by commanding nose-down elevator. The autopilot was then engaged, which because it was still in go-around mode, commanded nose-up trim. Flight crew attempted go-around after “alpha floor” protection was activated but combination of out-of-trim condition, high engine thrust, and retracting the flaps too far led to a stall. Fatal crash.

Date	Location	Airplane Type	Operator	Description
6/6/94	Hong Kong	A320	Dragonair	After three missed approaches due to lateral oscillations in turbulent conditions, a landing was made and the airplane went off the side of the runway. The flaps locked at 40-degrees deflection (landing position) just before the first go-around due to asymmetry. Asymmetry caused by rigging at the design tolerance combined with gust loads experienced. In accordance with published procedures, the flight crew selected [Configuration] CONF 3 for landing, which extended slats to 22 degrees. With autopilot engaged, lateral control laws correspond to control lever position. Under manual control, control laws correspond to actual flap/slat position. The configuration CONF 3, with flaps locked at 40 degrees, is more susceptible to lateral oscillations with the autopilot engaged. After a similar incident in November 1993, experienced by Indian Airlines, Airbus issued an Operations Engineering Bulletin to leave the control lever in CONF FULL if the flaps lock in that position.
6/21/94	Manchester	757-200	Britannia	Altitude capture mode activated shortly after takeoff, auto throttles reduced power, and flight director commanded pitch-up. Airspeed dropped toward V2 [take-off safety speed] before flight crew pitched the nose down to recover.
6/30/94	Toulouse	A330	Airbus	Unexpected mode transition to altitude acquire mode during a simulated engine failure resulted in excessive pitch, loss of airspeed, and loss of control. Pitch attitude protection not provided in altitude acquire mode. Fatal crash.
9/24/94	Paris - Orly	A310-300	Tarom	Overshoot of flap placard speed during approach caused a mode transition to flight level change. Auto throttles increased power and trim went full nose-up for unknown reasons (autopilot not engaged). Flight crew attempted to stay on path by commanding nose-down elevator but could not counteract effect of stabilizer nose-up trim. Airplane stalled but was recovered.
10/31/94	Roselawn	ATR-72	American Eagle	In a holding pattern, the airplane was exposed to a complex and severe icing environment, including droplet sizes much larger than those specified in the certification requirements for the airplane. During a descending turn immediately after the flaps were retracted, the ailerons suddenly deflected in the right wing down direction, the autopilot disconnected, and the airplane entered an abrupt roll to the right. The flight crew was unable to correct this roll before the airplane impacted the ground.

Date	Location	Airplane Type	Operator	Description
3/31/95	Bucharest	A310-300	Tarom	Shortly after takeoff in poor visibility and heavy snow, with auto throttles engaged, climb thrust was selected. The right engine throttle jammed and remained at takeoff thrust, while the left engine throttle slowly reduced to idle. The increasing thrust asymmetry resulted in an increasing left bank angle, which eventually reached about 170 degrees. The airplane lost altitude and impacted the ground at an 80-degree angle. Only small rudder and elevator deflections were made until seconds before impact, when the left throttle was brought back to idle to remove the thrust asymmetry. Fatal crash.
11/12/95	East Granby	MD-80	American Airlines	On a VOR-Distance Measuring Equipment (DME) approach, the airplane descended below the minimum descent altitude, clipped some trees, and landed short of the runway. Contributing to this incident was a loss of situation awareness and terrain awareness by the flight crew, lack of vertical guidance for the approach, and insufficient communication and coordination by the flight crew.
12/20/95	Cali	757-200	American Airlines	Unexpectedly cleared for a direct approach to Cali, the flight crew apparently lost situation awareness and crashed into a mountain north of the city. On approach, the flight crew was requested to report over Tulua VOR. By the time this waypoint was input into the flight management computer, the airplane had already flown past it; the autopilot started a turn back to it. The flight crew intervened, but the course changes put them on a collision course with a mountain. Although the ground proximity warning system alerted the flight crew and they responded, they neglected to retract the speed brakes and were unable to avoid hitting the mountain. Fatal crash.
2/6/96	Puerto Plata	757-200	Birgenair	After taking off from Puerto Plata, the flight crew lost control of the airplane during climb and crashed into the ocean off the coast of the Dominican Republic. Problems with the captain's airspeed indication were encountered during the takeoff roll and the first officer conducted the takeoff and initial climb out using airspeed callouts. Continued erroneous airspeed indications, possibly due to a blocked pitot tube, resulted in an over speed warning during climb. Shortly thereafter the stick shaker activated. The conflicting warnings (over speed and stall) apparently confused the flight crew. The airplane entered a stall from which it did not recover. Fatal crash.
12/31/96	Sao Paulo	Fokker 100	TAM	During takeoff, the pilots received an alert in error that the autopilot had disconnected when in actuality the right thrust reverser had unlocked and deployed.

Date	Location	Airplane Type	Operator	Description
12/8/05	Chicago	Boeing 737	Southwest	The National Transportation Safety Board (NTSB) determined “pilot’s failure to use available reverse thrust in a timely manner to safely slow or stop the airplane after landing, which resulted in a runway overrun.”
7/6/13	San Francisco	Boeing 777-200ER	Asiana	NTSB determined “probable cause of this accident was the flight crew's mismanagement of the airplane's descent during the visual approach, the pilot flying's unintended deactivation of automatic airspeed control, the flight crew's inadequate monitoring of airspeed, and the flight crew's delayed execution of a go-around after they became aware that the airplane was below acceptable glide path and airspeed tolerances. Contributing to the accident were (1) the complexities of the autothrottle and autopilot flight director systems that were inadequately described in Boeing's documentation and Asiana's pilot training, which increased the likelihood of mode error, (2) the flight crew's nonstandard communication and coordination regarding the use of the autothrottle and autopilot flight director systems, (3) the pilot-flying's inadequate training on the planning and executing of visual approaches, (4) the instructor pilot did not inadequately supervise the pilot flying, and (5) flight crew fatigue, which likely degraded their performance.”

FAA and NASA Contracted Research

The FAA and NASA have long been focal points for examining automation-induced problems. Barnhart et al. (1975), developed a list of five questions that should be asked after every accident or incident to determine the role of automation in the accident:

1. “Was all necessary and pertinent information acquired by the pilot? Was the information correct? Was it in a format that could be assimilated in time?
2. Was the information properly evaluated with respect to the quantity and quality?
3. Was the information properly processed? Did the pilot reach an appreciation of true aircraft state?
4. Did the pilot select the safest and wisest alternative? If not, what factors entered into the decision?
5. Was the decision effectively implemented?” (p. 16).

The paper also includes an interview guideline for pilots involved in an accident. In the following year, Billings, Lauber, Cooper, and Ruffell-Smith (1976) developed an epidemiological model for the study of human errors in aviation. It is presented in Figure 1. Note at the heart of the model is human error that is caused by a predisposing condition, attitude, or mental set. Each of these has been contributing factors in automation-induced accidents.

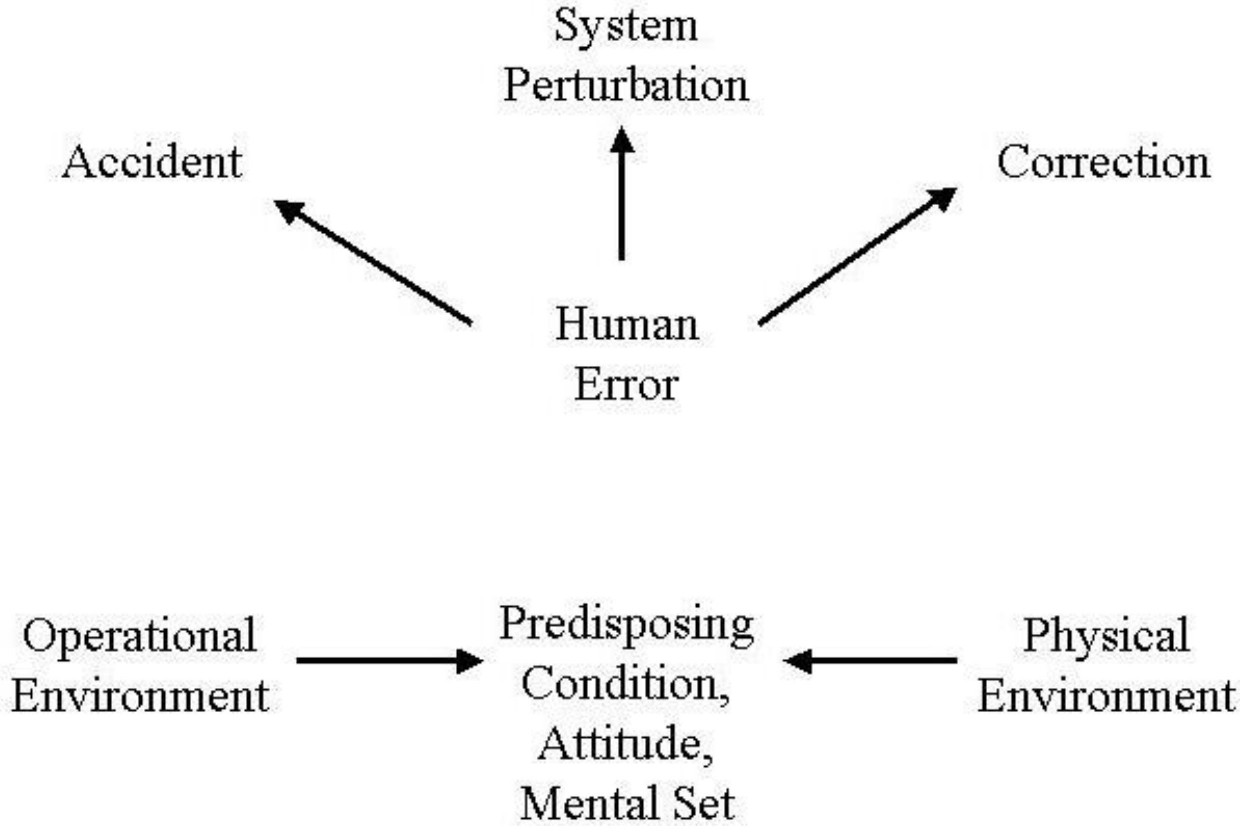

Figure 1. Epidemiological Model of Human Errors in Aviation (Billings, Lauber, Cooper, & Ruffell-Smith, 1976)

Bolman (1979) expanded the model and introduced the concept of “theories of the situation,” “a set of goals, beliefs, and behaviors that provides a coherent picture of what is happening and what action is appropriate” (p. 30). These theories of the situation are determined by the experiences of the person including training and practice. They are also influenced by core values, beliefs, skills, and outcomes. Helmreich (1979) stressed the need to consider the interaction of personality and situational factors. In one-person situations, a highly goal-oriented individual will excel. In multi-crew situations, a leader with both goal and group orientation will have the best outcome. Wegner (1980) added, “Of these human errors, poor technique in flight, maintenance error, and various supervisory unsafe acts are the three major categories” (p. 1).

In an excellent review, Wiener and Curry (1980c) listed the following problems associated with automation:

- Failure
- Automation-induced error compounded by crew error
- Crew error in equipment setup
- Crew response to a false alarm
- Failure to heed an automatic alarm

- Failure to monitor and
- Loss of proficiency

These authors went on to identify five problem areas. These are presented below:

1. Automation of control tasks:
    - Under what conditions is the operator as monitor a better failure detector than the operator as active controller?
    - Is there a warm-up delay when the operator transitions from monitor to controller?
    - Should the automated systems inform the operator after making a change or only make a change that has been acknowledged by the operator?
    - How do different levels of equipment reliability affect the operator's ability to detect failures?
2. Acquisition and retention of skills:
    - How quickly do manual skills deteriorate?
    - Can periodic practice prevent skill deterioration? If yes, at what frequency is practice required?
    - Are they alternatives for practice with the real system?
    - What techniques should be used to assure maintenance of skills?
    - Can automating some of the subtasks increase the rate of skill acquisition?
3. Monitoring of complex systems:
    - Does complex monitoring degrade with time on watch? Is the degradation perceptual, cognitive, or criterial?
    - How can the operator's alertness for rare signals be maintained?
    - How can an automatic system be more "interpretable"?

4. Alerting and warning systems:
    - What are the characteristics of an ideal alerting system?
    - What attributes make a false alarm rate unacceptably high?
    - Why do alarms go unnoticed?
    - Under what conditions do operators rely on alerting and warning systems as primary rather than as backup devices?
    - Under what conditions will operators check the validity of an alarm?
    - Should the responsible operator be given a preview alert prior to alerting the others?
    - Will the logic for smart warning systems be too complex for operators?
5. Psychosocial aspects of automation:
    - Will automation influence job satisfaction, prestige, and self-concept?
    - What precautions and/or remedies should be taken to combat the negative psychosocial consequences?
    - Should increased automation require changes in operator selection?
    - How should training programs be altered to deal with possible psychosocial effects?

In a joint NASA/industry workshop, Boehm-Davis, Curry, Wiener, and Harrison (1981) listed the following problems:

- Pilots are unlikely to use a system they do not trust.
- Training becomes more complex as pilots must be able to monitor the system in the fully automatic mode and control the system when it is in failure or manual modes.
- The newer automated system may be more complex than the manual system it replaces.

- Poor system designs exist due to: a) kluging to enable the system to handle all conditions under which it will be used including those for which it was not originally designed, b) being designed for individual pilot use not flight deck crew use, and c) presenting ambiguous or misleading information.
- The pilot can become bored and complacent as system monitor and be unable to respond quickly enough to system failures.

After a lifetime of work for the FAA, Billings (1997) summarized some of the problems of flight deck automation. One was decreased crew coordination due to a breakdown in the traditional roles of pilot flying and pilot not flying. In addition, there is a tendency for data entry and programming problems to draw both pilots' attention. In an earlier publication, Billings (1996), listed mishaps in which automation was a factor (see Table 2).

Table 2. ***Mishaps in Which Automation Was a Factor*** **(Billings, 1996)**

Mishap	Common Factors
DC-10 landing in [Collision Warning System] CWS mode	Complexity, mode feedback
B747 upset over Pacific	Lack of mode awareness
DC-10 overrun at John F. Kennedy Airport, New York	Trust in auto thrust system
B747 uncommanded roll, Nakina	Trust in automation behavior
A320 accident at Mulhouse-Habsheim	System coupling and autonomy
A320 accident at Strasbourg	Inadequate feedback
A300 accident at Nagoya	Complexity and autonomy
A330 accident at Toulouse	Inadequate feedback
A320 accident at Bangalore	System complexity and autonomy
A320 landing at Hong Kong	System coupling; lack of feedback
B737 wet runway overruns	System coupling
A320 overrun at Warsaw	System coupling
B757 climb out at Manchester	System coupling
A310 approach at Orly	System autonomy and coupling
B737 wind shear at Charlotte	System autonomy; lack of feedback

In the same year, Dhiomasaigh and McCarthy (1997) concluded from an analysis of aviation accidents that these accidents have the following characteristics in common: "tension between different sets of accountabilities, pressure on the pilot to make an immediate decision, and the pilot's sole responsibility for that decision" (p. 323).

In a more extensive study, Funk, Lyall, and Riley (1995) developed a taxonomy of flight deck automation problems from a review of the literature, accident reports, incidents reports, survey of experts, and a Function Allocation Issues and Tradeoffs (FAIT) analysis. The result is presented in Table 3. A shorter version of the results is presented in Funk and Lyall (1998). Funk and Lyall (2000) presented a more current summary. These authors point out the importance of automation designed addressing the problems of how the crew communicates with the automation, how the crew understands the automation, and the importance of feedback.

Table 3. ***Taxonomy of Flight deck Automation Problems and Concerns***
(Funk, Lyall, & Riley, 1995, pp. 268–269)

Category	% citations
A.1.1 Automation design problems and concerns	**44**
Automation design addresses primarily commercial incentives	<1
Automation systems are poorly designed	19
Automation lacks functionality or performance desired by pilots	4
Automation fails to perform according to pilot expectations	5
Automation does not control the aircraft the way pilots do	<1
Automation is too complex	3
Automation design is not human-centered	1
Automation usurps pilot authority	3
Automation protections can be lost	<1
Automation is not standardized	2
Automation is poorly integrated	1
Automation documentation is inadequate	<1
Pilot/automation interfaces are poorly designed	23
Automation controls are poorly designed	6
Automation displays are poorly designed	13
Automation obscures its own state from pilots	6
Automation obscure situation information from pilots	1
Automation provides too much information	1
Automation is not compatible with the ATC system	2
Automation use problems and concerns	56
Automation use creates problems	23
Pilots do not perform as well when using automation	<1
Pilots have difficulty assuming control from automation	1
Pilots have difficult recovering from automation failures	1
Pilot roles are different in automated aircraft	3
Pilots are out of the control loop when they use automation	2
Pilots place too much confidence in automation	7
Pilots abdicate responsibility to automation	<1
Pilots do not place enough confidence in automation	3
Pilots use automation when they should not	3
Pilots do not use automation when they should	<1
Pilots of automated aircraft may not require or maintain manual skills	4
Automation induces pilot fatigue	<1
Pilots lose automation skills is they do not regularly use automation	<1
Airline automation policies and procedures are inadequate	<1
Airlines do not adequately involve pilots in equipment selection	<1

Airlines do not consider automation expertise when assigning crews	<1
Poor automation system design creates problems	24
Automation increases pilot workload	2
Automation increases and reduces workload at the wrong times	2
Pilots focus too much attention on automation	8
Automation complexity creates problems	5
Pilots have difficulty deciding how much automation to use	<1
Pilots do not understand automation adequately	4
Pilots make mode selection errors	1
Automation is too complex for designers	<1
Transitioning between automated and conventional aircraft is difficult	1
Airlines do not keep automation databases up to date	1
Airlines do not provide adequate non-automated operations training	1
Airlines do not provide adequate automation training	4
Poor pilot/automation interface design creates problems	9
Pilot situation awareness is reduced by automation	2
Automation failures are difficult for pilots to assess	3
Crew coordination is worse in automated aircraft	4

In related work, Funk et al. (1999) created a web site (http://flightdeck.ie.orst.edu) to provide information regarding flight deck automation issues. In a survey of 47 experts, these authors identified the following six statements as having highly consistent agreement:

1. "Pilots are required to monitor automation for long periods of time, a task for which they are perceptually and cognitively ill-suited, and monitoring errors are likely.
2. Cultural differences are not adequately considered in automation design, training, certification, and operations. Because they are not considered, they have resulting effects on performance and how automation is used.
3. Transitioning back and forth between advanced-technology aircraft and conventional aircraft increases pilot training requirements.
4. Although automation may do what it is designed to do, design specifications may not take into account certain unlikely but very possible conditions, leading to unsafe automation behavior.
5. When two pilots with little automation experience are assigned to an advanced-technology aircraft, errors related to automation use are more likely.
6. Side sticks are not coupled with each other or the autopilot, reducing awareness of the other pilot's or the autopilot's inputs, resulting in reduced situational awareness, improper control actions, or both." (p. 113).

The first item has long been known. For example, Spady (1976) compared the scan patterns of seven pilots flying ILS approaches in a Boeing 737 simulator in a manual and a coupled mode. The coupled mode consisted of an autopilot without auto throttle. Spady found that pilots changed fixations more rapidly and looked at more instruments in the coupled than in the manual mode. Specifically, the time spent looking at the flight director in the manual mode was 73 percent, in the coupled mode only 50 percent. The scan rates were 1.2 seconds and 1.7 seconds, respectively.

The fourth item has long been known as well. For example, Chappell examined the Aviation Safety Reporting System for clues to causes of incidents. Altitude deviations were the most frequently reported incident. A common cause was failure to enter the correct altitude. An example of the difficulty in data entry is described by a first officer “I set FL290 in the computer and the preselect altitude but did not set it in the altitude alert window” (p. 2.3).

The last item is being addressed by BAE Systems in the United Kingdom. It is developing active side sticks and throttles to give pilots feedback of aircraft response (Nordwall, 2000).

The recurring problems associated with automation are poor vigilance, skill degradation, trust in automation, and complacency. Further, Besco and Funk (1999) would argue that a large percent of the automation-induced accidents is due to a lack of systems engineering and that these recurring problems are only symptoms.

References

Air Safety Week (2001). Pilot errors highlight continuing importance of basic flying skills. *Air Safety Week, 15(18)*, 1–4.

Barnhart et al. (September 1975). *A method for the study of human factors in aircraft operations* (NASA-TM-X-62472). Moffett Field, California: NASA Ames Research Center.

Besco, R. O. & Funk, K. (1999). Conceptual design guidelines to rediscover systems engineering for automated flight decks. *International Journal of Aviation Psychology, 9(2),* 189–198.

Billings, C. E. (1997). *Aviation Automation: The search for a human-centered approach.* Mahwah, New Jersey: Lawrence Erlbaum Associates.

Billings, C. E. (February 1996). *Human-centered aviation automation: principles and guidelines.* NASA Technical Memorandum 110381, Moffett Field, California: NASA Ames.

Billings, C. E., Lauber, J. K., Cooper, G. E., & Ruffell-Smith, H. P. (1976). *Retrospective studies of operating problems in air transport,* (pp. 585–590). Proceedings of Aircraft Safety and Operating Problems Conference, NASA Langley Research Center.

Boehm-Davis, D. A., Curry, R. E., Wiener, E. L., & Harrison, R. L. (January 1981). *Human factors of flight-deck automation – NASA/Industry Workshop* (NASA-TM-81260). Moffett Field, California: NASA Ames Research Center.

Bolman, L. (1979). Aviation accidents and the "theory of the situation." In G. E. Cooper (Ed.), *Resource Management on the Flight Deck* (p. 31). NASA Conference Publication 2120. Moffett Field, California: NASA Ames Research Center.

Chappell, S. L. *The role of the pilot and the effects of automation: Lessons from incidents,* 2.1–2.6.

Dhiomasaigh, L. N. & McCarthy, J. (1997). Conflicts of accountability in aviation accidents and incidents. In D. Harris (Ed.), *International conference on engineering psychology and cognitive ergonomics.* (pp. 1, 323–329). Aldershot, United Kingdom: Ashgate.

FAA (June 1996). *FAA Human Factors Team Report on interfaces between flight crews and modern flight deck systems.* Washington, DC.

Funk, K. & Lyall, B. (1998). *Human factors issues of flight deck automation,* (pp. 1, E23/1–8). Proceedings of the 17th Digital Avionics Systems Conference.

Funk, K. & Lyall, B. (2000). Identifying flight deck automation issues (2000-01-5595). *World Aviation Conference,* 1–8.

Funk, K., Lyall, B., & Riley, V. (1995). *Flight deck automation problems,* (1, 265–269). Proceedings of the Eighth International Symposium on Aviation Psychology.

Funk et al. (1999). Flight deck automation issues. *International Journal of Aviation Psychology, 9(2),* 109–123.

Helmreich, R. L. (1979). Social psychology on the flight deck. *National Aeronautics and Space Administration Conference Publication 2120,* 17–30.

Nordwall, B. D. (May 15, 2000). Side-stick controllers give tactile feedback. *Aviation Week and Space Technology.*

Reynard, W. D. (October 1983). *Incident reporting – Its role in aviation safety and the acquisition of human error data* (ADP002699). Moffett Field, California: NASA Ames Research Center.

Spady, A. A. (1976). *Preliminary report on airline pilot scan patterns during simulated ILS approaches,* (pp. 603–616). Proceedings of Aircraft Safety and Operating Problems Conference at NASA Langley Research Center.

Wegner, K. W. (May 1980). *A tentative taxonomy of human interactive factors in aircraft mishaps* (AFOSR-TR-80-0595). Chestnut Hill, Massachusetts: Boston College.

Wiener, E. L. & Curry, R. E. (June 1980c). *Flight-deck automation: Promises and problems* (NASA-TM-81206). Moffett Field, California: NASA Ames Research Center.