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Increased Reliance on Automation May Weaken Pilots' Skills for Managing System Failures

A report issued by the U.K. Civil Aviation Authority says that pilots are not receiving adequate training in the use of automated systems, including when and how to interrupt an automated process with manual inputs.

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FSF Editorial Staff

Increased reliance on automation by flight crews has created a risk that crewmembers may no longer have the skills required to "react appropriately to either failures in automation, programming errors or a loss of situational awareness," the U.K. Civil Aviation Authority (CAA) Safety Regulation Group said in a report on the role of automation on the flight deck.

The report was based on a review of earlier studies of flight deck automation, a review of relevant incidents that occurred in 2002 and 2003 involving major aircraft types and interviews with personnel from airline training departments, type rating training organizations, the CAA Personal Licensing Department, CAA Flight Operations Inspectorate and specialists in crew resource management (CRM)/human factors.

"The research indicated that there was much evidence to support the concern that crews were becoming dependent on flight deck automation," the report said. "Furthermore, the new human task of system monitoring was made worse by the high reliability of the automation itself."

Data are scarce on whether loss of manual flying skills occurs among the crews of highly automated aircraft, but anecdotal evidence from interviews and from earlier studies indicates that this is a concern in the aviation industry. In addition, several reports submitted under the U.K. CAA Mandatory Occurrence Reporting (MOR) Scheme[1] showed that crews "do respond inappropriately having made an incorrect diagnosis of their situation in which the automation fails," the report said.

For example, in one MOR incident, "disconnecting the autopilot following an overspeed in turbulence then resulted in altitude busts [deviations from assigned altitudes/flight levels]," the report said. "If pilots had a better understanding of the automation, then it is likely that the need for manual flying could have been avoided and thus the subsequent level bust [also could have been avoided]."

Automation failures can be understood by first acknowledging that, even under "normal" conditions, the relationship between humans and machines is inadequate.

"Even with a fully serviceable system, the crew, under certain situations, are already under increased workload to compensate for the design of the system, thereby producing a deterioration in situational awareness brought on in part by the automation itself," the report said. "Therefore, the consequence of even the smallest of 'failures' may, depending upon [the] situation, jeopardize the safe conduct of a flight."

The report said that there are several categories of automation failures.

One type is *automation system failure,* which involves the failure of an entire system — such as the autopilot, autothrottles or flight management system (FMS) — or a partial failure (failure of one system function) — such as altitude hold.

Flight crew operating manuals and computer-based training contain information on how the systems function, including information about normal operations, hardware failures and warning messages for total failure of the autopilot, autothrottles and FMS.

"Clearly, these failures will present the crew with a rule-based procedure that can be applied to recover or mitigate the situation," the report said. "It is the role of the manufacturer to provide recommended procedures in the form of checklists; however, these procedures specifically do not include elements of 'airmanship.' Operators should ensure that training programs include means and standards to be met regarding the interaction of human performance and limitations with changes to the normal operation of the automation. This will, necessarily, be material that is in addition to that provided by the manufacturer. Procedures should be taught and trained in the context of an operating environment; [that is,] the procedure should not be covered as a button-pushing drill but more to highlight the differences to the workload and management of the operational task."

The report said that Airbus and Boeing provide information on procedures for the input of data and the cross-checking of system responses, and operators have published additional information designed to guard against complacency and human error. Nevertheless, earlier studies have found that even the pilots who have access to the written information "still confuse modes or make inappropriate decisions," the report said.

Programming/input failure occurs when the system is functioning correctly but with incorrect data — either because of an error by the crew or because an associated system or subsystem is providing incorrect data. Such events are rare; therefore, human reaction to them often involves complacency.

For example, the report cited a situation in which a crew received a ground-proximity warning system (GPWS) warning as they conducted a very-high-frequency omnidirectional radio (VOR) approach to Addis Ababa, Ethiopia. The GPWS warning was received while the VOR signal and the FMS provided "compelling data that the aircraft was on track," the report said; at the same time, the nondirectional beacon (NDB) information contradicted the VOR/FMS information. In fact, the VOR was incorrect, and as a result the FMS position also was incorrect; the airplane was 4.5 nautical miles (8.3 kilometers) to 7.7 nautical miles (14.3 kilometers) off track.

"The weighting of belief was in favor of the automation," the report said. "If the crew had been flying a 'raw' VOR approach, then the only other information available (i.e., the NDB) would have featured more prominently as a disagreement."

(The report did not provide other details about the event, including the type of aircraft, the operator or the outcome of the incident.)

Organization failure occurs when the organization and management of the flight operation "fail to ensure that the policies and procedures stipulated are coherent with the operational task," the report said.

For example, the report cited incident reports that described cases in which "the use of ACARS [aircraft communications addressing and reporting system] to provide load-sheet information during taxi appears efficient from a commercial point of view but may provide a distraction during a critical moment prior to takeoff."

The report said, "there is a concern that pilots will, in time, become used to merely reading data from one computer output into the input for another computer without thinking about the accuracy or reasonableness of the data." In comparison, when pilots use tabular data or graphical data — although there is a risk of mis-reading the information — a range of data is presented. ACARS provides only one answer; therefore, an incorrect input figure may be difficult to discern.

The report cited one example in which the takeoff weight for an Airbus A340-600 was incorrectly entered as "240T" (about 240 metric tons), instead of "340T." The takeoff performance figures calculated by ACARS were "quite reasonable" for an A340-300 and, therefore, were familiar to the crewmembers, who were type-rated in both models and did not recognize the error. Instead, the relief pilot identified the error.

The report said, "Integration of all aspects of human cognitive behavior and the requirements of a commercial operation are necessary if policies and procedures are to be optimized for safety, as well as efficiency considerations. Regulatory explanatory material should provide information to operators on specific areas to include in training programs and best practice for policies and procedures."

Design failure occurs as a result of the design of the automation. The report said, "The architecture of flight deck automation is based on rationalistic principles that do not readily align with the mental models pilots have for the manual flying task. … The way forward is for the evolution of current designs rather than revolution; however, we still have a problem of mitigating the human machine problems of [existing] system designs."

Work toward improving system designs can take years; even after design changes are implemented, in-service designs may remain in use for 30 years, resulting in "workarounds" — methods of coping with known problems. For example, one airline decided, at the introduction of a new aircraft, not to use its full automation capability; instead, as crews gained experience, procedures were adapted and training was developed for specific automation functions.

Licensing Requirements Change Slowly

The report said that a review of the Joint Aviation Authorities' flight-training requirements (Joint Aviation Requirements–Flight

Crew Licensing 1 [JAR–FCL 1]) showed that before the requirements were issued in 1997, there was no analysis of training to determine whether the existing standards were effective and comprehensive.

Nevertheless, a review of standards reveals "little change in philosophy over the years, despite the acknowledged changes in the operational task facing pilots," the report said. "The current [FCL] requirements indicate what the training courses should achieve in terms of syllabus and learning objectives, but there is little guidance on how to achieve the aim. This level of detail is left to the flight training organizations and airlines. The structure of the license requirements has changed little since the end of the Second World War."

The theoretical knowledge requirements for the airline transport pilot license (ATP), discussed in JAR–FCL 1.470, present automation as a system rather than as "an integral component of the flight deck task," the report said. "[After] the student has gained his [ATP] theoretical knowledge credits, he has acquired a limited level of declarative knowledge [facts] but very little procedural knowledge [how to perform specific tasks] that is relevant to working with the automation of a modern flight deck."

Theoretical knowledge for type ratings also is presented as declarative knowledge. Pilots assimilate some procedural knowledge through their practical training in the use of the autopilot, autothrottles and FMS.

"The training is limited to use of systems in normal mode and with hardware failures only," the report said. "In fact, the complex nature of these systems means that the limited exposure of these sessions is often accompanied by the phrase 'don't worry about that — you will pick that up on the line.'"

Nevertheless, training captains said that opportunities were limited during line training to demonstrate anomalies in automation systems, "unless the situation just happened to present itself," the report said. "So at the end of the type-rating training, the pilot is competent to manage the system in a normal situation based on declarative knowledge but has little experience or procedural knowledge of normal operation and even less in the case of failure (i.e., non-normal situations)."

Proficiency skills test requirements contained in JAR–FCL 1 and in U.K. CAA Standards Document 24, *Guidance to Examiners: Multi-pilot Aeroplanes Type Rating Skill Tests and Proficiency Checks*, emphasize the pilot's manual flying skills; controlling the aircraft flight path with the autopilot and FMS is classified as one of the "other aircraft systems" skills, and is evaluated once every three years with no stipulation as to the extent of competence required. Standards Document 24 mentions "automatics," but, the report said, the words "do little to highlight the complex nature of modern automation and the degree of competence that is necessary for safe and consistent application of this tool across the range of situations that are commonly met in contemporary commercial operations."

From the beginning of their training, pilots learn to control the flight path manually, with "feed-forward" behavior that involves recognizing an error in flight-path performance and making a control input in anticipation of the desired response, the report said.

"They think ahead in a pro-active manner," the report said. "However, studies have shown that pilots operating modern automation for flight path control do not have the knowledge or understanding to predict the behavior of the automation based on detection of an error and selection of a control input. They cannot always predict the behavior or feedback cues of the systems modes; as a result, it may be said that they behave in a feedback or reactive manner — they are 'behind' the aircraft. …

"It may be concluded that pilots lack the right type of knowledge to deal with control of the flight path using automation in normal and non-normal situations. This may be due to incorrect interpretation of existing requirements or lack of a comprehensive training curriculum that encompasses all aspects of the published requirements. It is suggested that there should be a shift in emphasis in the way automation for flight path control is taught and trained. Further research is required to identify the cause and provide a solution."

CRM Overlooks Human-machine Interactions

In recent years, CRM for flight crews has emphasized psychological topics, behavioral topics and physiological topics. Topics involving practical applications of the cognitive elements [thinking, planning and remembering] of human performance, especially those involving human-machine operations, have received less attention and are less understood, the report said.

In the United Kingdom, many training pilots and management pilots were exempt from a requirement that they complete a human performance and limitations exam.[2] The report said that, after interviews, these pilots could be grouped into two classes: those who "thoroughly endorse all aspects of human performance and limitations, including cognitive limitations, or those who consider CRM to be limited to behavioral aspects of flight deck operation.

"It appears that the requirements for training in, and the application of, the cognitive elements of human performance on the flight deck and their impact on the operations of highly automated systems [have] been better understood by some than others. … There was a loophole in the introduction of the requirements for CRM training that has resulted in many of those responsible for the oversight of training programs not fully understanding all the cognitive aspects of human performance limitations."

Line-oriented flight training (LOFT) can be used to provide procedural knowledge of how to fly an airplane using automation. Nevertheless, LOFT is not fully included in budgets for training, the report said.

Training in Automation Remains Inadequate

Training does not prepare flight crews "to properly monitor the automated functions of the aircraft in all foreseeable situations or … to intervene in an automated process," the report said. "Neither does it prepare crews to conduct an adequate range of tasks using the automation."

The report recommended changing the methods of teaching and training flight path control to use procedural training instead of declarative training. In addition, the report said, "The assumption that much training can be carried out on the line should be questioned. Operators are unable to demonstrate a full range of circumstances or effects during passenger flights."

The report said that additional research is required to determine what type of training should be provided in the use of automation, what manual flying skills are degraded among crewmembers of highly automated aircraft and how this problem should be addressed, how best to incorporate the cognitive elements of CRM into automation training, and what methods should be used to ensure effective communication of the cognitive aspects of human performance and limitations to training pilots and management pilots who were exempt from the human performance and limitations exam.♦

[FSF editorial note: This article, except where specifically noted, is based on U.K. Civil Aviation Authority Paper 2004/10, *Flight Crew Reliance on Automation*, written by Simon Wood of Cranfield University and published Dec. 22, 2004. The 44-page report contains an appendix.]

Notes

1. Civil Aviation Publication (CAP) 382, *Mandatory Occurrence Reporting Scheme* (sixth edition, March 17, 2003), says that the U.K. Civil Aviation Authority (CAA) Mandatory Occurrence Reporting (MOR) Scheme is intended to provide information to CAA about hazardous or potentially hazardous incidents and defects and to provide for dissemination of knowledge about these occurrences "so that other persons and organizations may learn from them." The confidential reporting system is designed to yield information to improve flight safety, not to attribute blame.

2. The exemption applies to pilots who received pilot licenses before Jan. 1, 1992. They are, however, required to undergo initial crew resource management (CRM) training on joining any new company and to undergo annual recurrent training.