Training for Automation Use

(NAG2-1285)

Final Report

Submitted to the NASA Ames Research Center

Submitted by:
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December, 2003

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Executive Summary

Automated aids and decision-support systems are becoming the norm in US Regional Airline operations, as regional carriers upgrade to jet aircraft, and increase the sophistication of their fleet. Particular attention must be paid to the impact of automation for regional pilots, and to the special training paradigms necessary to teach the safe and effective use of automation in their operational arenas. Much of the research that has been done thus far on automation-related issues and problems has focused on aircraft and pilots of major airlines, and automation training programs have typically assumed a high level of flying expertise (e.g., Funk, Lyall, & Riley, 1995; Funk et al., 1999; Mosier, Skitka, Heers & Burdick, 1998; Mosier, Skitka, Dunbar, & McDonnell, 2001; Sarter & Woods, 1994, 1995; Woods & Sarter, 1998). Much less work has been done that specifically addresses automation issues in regional carriers, in which pilots with a generally lower level of experience are moving into aircraft with a wide range of automated capabilities.

Our research has addressed these issues, drawing from previous work of both of the principal investigators concerning automation and information use (e.g., Funk & Lyall, 1997; Funk, Lyall, & Riley, 1995; Lyall, Niemczyk, Fint, & Funk, 1997; Lyall, Vint, Niemczyk, Wilson, & Funk, 1998; Mosier et al., 1998, 2001; Skitka, Mosier, & Burdick, 1999). The broad goals of our work during this project have been to: a) identify and define relevant characteristics of the target population (Regional Air Carriers); b) analyze and classify training needs and training objectives for this population; and c) formulate recommendations for training objectives that could be implemented in a CD or internet-based training tool. This summary contains an abbreviated description of our approach and our work, supplemented by the attached publications (see Appendix). Our primary focus in this report will be on delineating recommendations for regional air carrier automation training objectives.

Approach

During the past four years, we have utilized a variety of complementary approaches, methods, and data sources to accomplish the goals stated above. Each analysis yielded a unique perspective on automation issues and problems in regional carriers, and was used to inform our recommendations.

Analyses:

- ASRS incident analyses (see 1999, 2000 progress report; Lyall, Harron, & Wilson, 2002; Mosier, Keyes, & Bernhard, 2001; 2003)
- NTSB incident analysis (see 2001, 2003 progress reports)
- Interviews with training personnel at Regional Air Carriers (see 2000 progress report)
- Demographics comparison – RAA v. ATA Airlines (see 2000 progress report; Lyall, Harron, & Wilson, 2002)

- Automation issues comparison – RAA v. ATA Airlines (see 2000 progress report; Lyall, Harron, & Wilson, 2002)
- Paper-and-pencil scenario study (see 2000 progress report; Mosier, 2000; Mosier, Bernhard, & Keyes, 2001; Mosier, Keyes, & Bernhard, 2003;)
- Operational and flight deck comparisons – RAA v. ATA Airlines (see 2001, 2002 progress reports)
- Internet-based scenario study (see 2001, 2002 progress reports; Mosier, Lyall, Sethi, Wilson, McCauley, Harron, Khoo, Hecht, Richards, & Orasanu, 2003).

Training Objectives and Recommendations

Source: Incident analyses - automation issues

The issue of inadequate understanding of automation was more prevalent in the regional airline incident reports than in the major transport reports. Inadequate understanding of automation was found to be a relevant issue in just under 14% of the regional airline incident reports (see Table 13 in December 2001 progress report) compared to only about 1% of the major transport incident reports. This difference may be partially explained by the demographics of the regional airline population compared to that of the major airlines. The regional airline pilots are typically less experienced, have a higher turnover rate, and may fly a wider range of airplane types. Each of these factors may affect the regional airline pilot's understanding of flight deck automation and lead to incidents that result from inadequate understanding of the automation.

General Training Objectives:

- Provide basic information for pilots to develop knowledge of automation and its use in general.
- Provide general automation use activities to build general skills related to the use of automation and when and how it should be used.

Source: Incident analyses - automated systems

The automated system that was involved in almost half of the incident reports independent of the type of airplane was the related to the autopilot/autopilot controls/autopilot modes (see Table 1 in December, 2001 progress report). This was also the system most often indicated when looking at each of the airplanes separately.

General Training Objectives:

- Provide information for pilots to develop general knowledge of the autopilots, autopilot functions, autopilot controls, and autopilot modes.
- Provide exercises for pilots to begin building general skills related to the use of autopilots, how to operate them, and how to choose the proper mode for general situations.

System-Specific Training Objectives:

- Provide information for pilots to develop knowledge about their specific airplane autopilot (functions, controls, and modes) and how they differ from autopilots in general, if at all.
- Provide exercises for pilots to build skills related to the use of all autopilot functions, controls, and modes.
- Provide training device or simulator scenarios for pilots to further develop skills in using the autopilot functions, controls, and modes in a broad range of operational situations defined by the types of operations flown by the airline.

Besides the incidents related to the autopilot, which is a type of control automation, there were incidents related to the other two types of automation: information automation and management automation. The types of incidents that occur are different for the three types of automation and it may be useful for the pilots to understand these differences.

General Training Objectives:

- Provide information for pilots to develop knowledge about the three types of automation and their use in the flight deck.
- Provide information for pilots to develop knowledge about the different types of vulnerabilities for error that may occur with the use of the different types of automation.

System-Specific Training Objectives:

- Provide information for pilots to develop knowledge related to their airplane and systems that provide the information automation, control automation, and management automation.
- Provide information for pilots to develop knowledge related to when to use each of the functions of each of the automated systems and their modes.
- Provide exercises for pilots to begin developing skills related to the use of each of the automated systems in the three automation types.
- Provide scenarios in training devices or simulators that allow the pilots to build skills for using each of the automated systems in a broad range of operational situations defined by the types of operations flown by the airline.

It should be noted that at the time of our analyses, only about 38% of the RAA fleet was FMS equipped (compared with about 63% of ATA member aircraft). Incident reports and automation issues reflected this disparity, with relatively few RAA reports citing problems or issues associated with the FMS. For example, the frequency of "Mode transitions may be uncommanded by pilot" differed across populations, ranking 4^{th} in frequency in the major transport analysis, but 12^{th} in the regional airline analysis.

Currently, FMS-equipped aircraft such as the CRJ, Embraer 145, DeHavilland Dash 8, ATR 42 and 72, BAe Jetstream 41, and Dornier 328 represent the fastest growing segment of the regional airline population. As regional airlines increase the number of FMS equipped aircraft in their fleet, particular attention will need to be paid to FMS issues such as mode transitions and navigational requirements.

Source: RII training report (Lyall, Vint, Niemczyk, and Wilson, 1998)

One critical element of developing training objectives is understanding the organization's policies and procedures for the use of automation. If these are not clearly defined, it is more difficult to develop clear training objectives and programs that will effectively teach the pilots how to use the automation. The organization's philosophy of automation use is important, as well as specifics about when and how it is recommended that the automation be used. Some organizations also have policies (sometimes informal) stating how often they would like their pilots to hand fly the airplane. All of this guidance is important for developing thorough, consistent training objectives for automated airplanes.

Airline-Specific Training Objective:

- Provide information for pilots to develop the knowledge related to the organization's automation-use philosophy, policies, and procedures. If there is guidance that the airline wants to give pilots about how often they should hand-fly the automated airplane this should be included.

'The first general lesson learned is that automated aircraft have complexities that are not present on traditional aircraft. These complexities create challenges for training development and implementation. Training managers and developers must carefully determine how to design training programs to present the complex systems while still teaching the necessary information to fly the basic aircraft without the automation.

Recommendation 1: Ensure that the information for flying the basic aircraft is effectively included in the training program.' (from RII training report)

General Training Objectives:

- Provide information to develop all necessary knowledge about how to fly the airplane without the automation.
- Provide exercises for pilots to begin developing skills related to flying the airplane without the automation.
- Provide training device and simulator scenarios for the pilots to develop the skills to fly the airplane without the automation.

The training report includes 14 other recommendations. All may be applied to the regional airlines:

Recommendation 2: Pilots should be provided hands-on experience with the automation as early in the program as possible.

Recommendation 3: Automated systems should be taught throughout the training program. Training automation should be integrated into multiple modules of the program rather than as only a stand-alone module.

Recommendation 4: Hands-on interaction with the automated systems by whatever means should be structured in a manner that ensures effective progression through the training program and does not encourage the learning of improper practices or understanding of the automated systems.

Recommendation 5: Consider using a building block approach to integrating the training programs for the automated aircraft. Ensure that the objectives of each block of the program are defined along with how the pilots will accomplish that block using particular training devices. Also include the specific training objectives and approach to integration in the instructor-training program.

Recommendation 6: Instructors should be available during all training events when the pilots are learning about or interacting with the automated systems.

Recommendation 7: The training programs for instructors on the automated aircraft should be enhanced to teach them techniques for consistently recognizing and responding to pilot needs as they arise during the program.

Recommendation 8: During training, a comfortable atmosphere should be established that clearly communicates training objectives and provides opportunities for pilots to ask questions and develop their own understanding of the automated systems.

Recommendation 9: Ensure that all training devices used to teach the automated systems include full functionality of those systems and allow pilots to use them in all the ways that they would be able to use them in the aircraft.

Recommendation 10: Attention should be given to the development and use of CBT in the training programs for automated aircraft so that it includes those characteristics that have been shown to be effective. In particular the CBT should be interactive and present information in a manner that facilitates use of the automated systems later in line operations.

Recommendation 11: CRM-related topics should be taught throughout the training program.

Recommendation 12: Crew-based training should be used whenever possible in automated aircraft training programs.

Recommendation 13: Training exercises and events that are scenario-based should be included throughout the training program.

Recommendation 14: Do not add information and requirements to the training program unnecessarily.

> Recommendation 15: To the extent possible, the logic underlying the automation and the limitations of the automation should be explicitly taught in the program.

Source: Experimental scenario studies[1]

The automated cockpit is essentially an electronic, deterministic environment; cues that were once available only in the outside environment have been brought into the cockpit and displayed as highly reliable information rather than probabilistic indications. This means that the need for *correspondence* (i.e., empirical accuracy in using probabilistic cues for diagnosis, judgment, and prediction) has lessened and the need for *coherence* (i.e., rational and consistent use of all relevant information in diagnostic and judgment processes) has greatly increased. Our previous work on automation bias demonstrated that non-coherent processes, that is, the heuristic use of automated information in the cockpit as a shortcut for vigilant information seeking and processing, could result in omission and commission errors.

One important focus of our work has been the exploration of factors impacting pilot information/data gathering and use for diagnosis and decision making. Results of our paper-and-pencil and internet-based scenario studies suggested that *when data are made equally salient*, pilots do not exhibit a systematic preference for automated information. Additionally, *when data are made equally salient*, whether the initial information about a problem is presented as coming from an automated source (e.g., EICAS) or another source (e.g., ATC, copilot, altitude or speed indicator, etc.) does not in itself impact the coherence of diagnosis and decision-making processes. This suggests that the roots of automation bias and automation-related errors may lie primarily in the physical and psychological salience of automated displays. Not only may the design of automated displays enhance their physical prominence within the cockpit, but also current training philosophies on the use of automated displays may amplify their psychological import. For example, training instructors at one regional carrier disseminate the philosophy that 'the light on the overhead panel is the rumor and what is displayed on the EICAS is the fact.' Given this, pilots may be disinclined to perform a thorough information search when all they think they need to do to get the 'facts' is look at automated displays. The motivation to check all information sources may be further eroded by experience in automated aircraft, a notion supported by earlier findings that more experienced pilots was *more likely* to commit omission errors (Mosier et al., 1998).

Our internet-based scenario study demonstrated that congruence of information was a key factor in the coherence of diagnostic processes and resultant accuracy (see Mosier et al., 2003). In general, pilots who checked more information were more accurate ($r = .45$, $p<.01$), and pilots were more accurate when all information was consistent with a particular diagnosis than when information incongruencies were present. Interestingly, pilots' confidence in their diagnoses was unrelated to their accuracy, and was negatively related to the amount of information they checked – the less they checked, the more confident they were of their diagnosis ($r = .23$, $p<.05$).

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[1] Note: The internet-based scenario study is described in some detail here because results have not been discussed in previous reports.

Importantly, we found that time pressure, a common factor in airline operations, had a strong negative effect on diagnosis and decision making, and that the presence of conflicting information heightened these negative effects. Overall, pilots responded to conflicting information by taking more time to come to a diagnosis, checking more information, and performing more double-checks of information. However, they were less thorough in their information search when pressed to come to a diagnosis quickly than when under no time pressure. This meant that they tended to miss relevant information, resulting in lower diagnosis accuracy, particularly when information conflicts were present.

It will be important, then, to help regional airline pilots maintain coherent diagnosis and decision-making processes in automated aircraft. Pilots will need to be encouraged to cognitively override the push of time pressure to ensure a thorough and complete information search for accurate diagnoses.

General Training Objectives:

- Provide information to help pilots develop an accurate mental model of automated system functioning.
- Provide information for pilots that pinpoints coherence hazards inherent in automated systems and displays (e.g., numerical displays that may signify different states depending on current mode).
- Provide scenarios in training devices or simulators that allow the pilots to build skills for processing and using information analytically as appropriate.
- Provide scenarios in training devices or simulators that allow the pilots to build skills for thorough information search in diagnosis and problem solving.
- Provide scenarios in training devices or simulators that allow the pilots to build skills for coherent information use, particularly under conditions of time pressure
- Provide scenarios in training devices or simulators that allow the pilots to experience information/display conflicts and to build skills for their resolution.

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APPENDIX

Publications and presentations from NASA Grant #NAG2-1285, Training for Automation Use

Publications

Lyall, B., Harron, G., & Wilson, J. (2002). Automation issues in regional airline operations. In E. Salas (Ed). *Advances in human performance and cognitive engineering research: Automation*. NY: JAI Elsevier Science. (pp. 201-212)

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