Lyall, B. & Funk, K. (1998). Flight Deck Automation Issues. In M.W. Scerbo & M. Mouloua (Eds.) *Proceedings of the Third Conference on Automation Technology and Human Performance held in Norfolk, VA, March 25-28, 1998.* (pp. 288-292). Mahwah, NJ: Lawrence Erlbaum Associates.

Flight Deck Automation Issues

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Hundreds of articles and presentations have addressed problems and concerns with flight deck automation. Many have raised general concerns about the approaches taken to automation use philosophies and automation design. Others have addressed specific problems or concerns identified with particular designs or implementations of automation.

The first phase of our research identified 114 human factors problems and concerns with flight deck automation (Funk, Lyall, & Riley, 1995). In the second phase of our project we used a wide variety of sources to locate and record evidence related to these problems and concerns. Because an *issue* is "[a] point of discussion, debate, or dispute ..." (Morris, 1969), we decided to change our terminology and refer to these problems and concerns as *flight deck automation issues*. This is what will be used for the remainder of this paper.

The sources we reviewed for evidence included accident reports, documents describing incident report studies, and documents describing scientific experiments, surveys and other studies. We also conducted a survey of individuals with broad expertise related to human factors and flight deck automation (human factors scientists, aviation safety professionals, pilots, and others), and evaluated a related set of ASRS incident reports. We reviewed these sources for data and other objective information related to the issues. For each instance of evidence we qualitatively assessed the extent to which it supported one side of the issue or the other, and assigned a numeric strength rating between -5 and +5. We assigned a positive strength rating to evidence supporting that side of the issue suggested by its issue statement (supportive evidence) and a negative strength rating to evidence supporting the other side (contradictory evidence).

For example, consider the statement of *issue065: Pilots may lose psychomotor and cognitive skills required for flying manually, or for flying non-automated aircraft, due to extensive use of automation.* If we found evidence in a source indicating that pilots lose manual flying skills due to extensive use of automation (at least under some circumstances), we recorded the related excerpt from the source document and assigned this supportive evidence a positive rating, perhaps as great as +5. If we found evidence in a source indicating that pilots can and do maintain manual proficiency even with extensive use of automation (at least under some circumstances), we recorded the related excerpt and assigned this contradictory evidence a negative rating, perhaps as great as -5.

We developed detailed strength assignment guidelines for evidence from each type of information source. For example, in pilot surveys of automation issues, if at least 90 per cent of the respondents were in agreement with a statement consistent with an issue statement, we assigned a strength rating of +5. If at least 90 per cent were reported as disagreeing with a statement consistent with an issue statement, we assigned a strength rating of -5. During the process of collecting and recording evidence, we revised, updated, consolidated, and organized the issues, finally yielding 92 flight deck automation issues.

THE FLIGHT DECK AUTOMATION ISSUES WEBSITE

Our work has yielded a body of information consisting of flight deck automation issues, unsubstantiated citations of those issues, supportive and contradictory evidence for the issues, and a bibliography of documents related to the issues and flight deck automation in general. To disseminate this information, we created a World Wide Web site accessible by the following Universal Resource Locator:

http://flightdeck.ie.orst.edu/

The website includes details about all aspects of our project. In particular, the methodology for each component (including strength rating assignment) is fully described, the list of flight deck automation issues is presented, several taxonomies organizing the issues under different sets of categories are included, and access to a searchable, read-only version of our database is provided. Though we hope to continue adding to it, the database currently contains the following:

- a bibliography of more than 500 automation-related documents,
- more than 2,000 unsubstantiated citations of possible problems and concerns (from Phase 1),
- 92 flight deck automation issues,
- more than 100 studies reviewed for evidence related to those issues,
- more than 700 records of supportive and contradictory evidence related to the issues, and
- 282 ASRS incident reports reviewed for evidence in our own incident study.

EVIDENCE APPLICATION

The following example is given to show how the searchable database on the website can be used. A search of the current database asking for evidence associated with the problem “Pilots may not understand the structure and function of automation or the interaction of automation devices well enough to safely perform their duties (Issue105),” would identify 51 evidence records. These 51 records are from 14 references - five accident reports, two experiments, five survey studies, one observation study, and one incident study. Thirty-seven of the evidence records were assigned positive strength ratings (i.e. provide information consistent with the issue statement about how pilots may not understand automation), and 14 evidence records were assigned negative strength ratings (provide information refuting the issue statement about how pilots have been shown to understand automation). Each of the evidence records includes the strength of the evidence, the bibliographic reference for the source, an excerpt from the document stating the information upon which the evidence was based, and the type of source it comes from (e.g. accident report, survey, etc.) A representative subset of this evidence query is presented in Table 1.

The evidence information can be used to summarize the perspectives and nuances that have been documented about this issue, as well as provide a starting point for identifying and evaluating potential solutions. This type of query can be accomplished for any of the issues by using the database search capabilities included on the website. It is our goal to keep the database current to allow researchers and practitioners to have a common base of information from which to work, and to provide a means for coordinating future efforts to address flight deck automation issues. The database can also be queried by keyword or for evidence records related to other factors like a particular reference source or study type.

Table 1 – Sample evidence records for "Pilots may not understand the structure and function of automation or the interaction of automation devices well enough to safely perform their duties (Issue105)."

Strength	Evidence Excerpt	Source Reference
-4	"Another problem related to mode engagement was the attempt to activate a mode without the prerequisites for this activation being met. Fifty percent of the transitioning pilots and 1 of the 14 experienced pilots tried to engage VORLOC without being in the manual radio mode as required." That is, 16 of 20 (80%) did it correctly.	Sarter, N.B., & Woods, D.D. (1994)
-3	Statement 34: "There are still modes and features of the B-757 FMS that I don't understand." From the histograph of the responses in Phase 1 of the study, 34% of the pilots agreed or strongly agreed with the statement and in Phase 2 of the study, 21% of the pilots agreed or strongly agreed with the statement while 53% disagreed or strongly disagreed in Phase 1, and 64% disagreed or strongly disagreed in Phase 2. The neutral responses were 13% in Phase 1 and 15% in Phase 2.	Wiener, E.L. (1989)
-2	"... when asked to intercept the LAX 248 [degree] radial, all 6 of the transition pilots had difficulties carrying out the task using LNAV, as compared to only 7 of the 14 experienced pilots." That is, 7 out of 20 (35%) did not have difficulties.	Sarter, N.B., & Woods, D.D. (1994)
+2	Statement 34: "There are still modes and features of the B-757 FMS that I don't understand." From the histograph of the responses in Phase 1 of the study, only 34% of the pilots agreed or strongly agreed with the statement and in Phase 2 of the study, only 21% of the pilots agreed or strongly agreed with the statement while 53% disagreed or strongly disagreed in Phase 1, and 64% disagreed or strongly disagreed in Phase 2. The neutral responses were 13% in Phase 1 and 15% in Phase 2.	Wiener, E.L. (1989)
+3	"... the training observations indicate that pilots do not perceive the FMS as one large integrated system consisting of a variety of closely related, interacting subsystems such as the MCP or the CDU. ... Our data show that pilots think of and operationally use the MCP and CDU as, at least two different systems."	Sarter, N.B., & Woods, D.D. (1992)
+4	"The GA mode becomes available when descending below 2,000 ft radio altitude with autothrottles armed. Out of 20 pilots, only 5 [25%] recalled the altitude at which this occurs. Eight pilots (40%) knew that the availability of the mode depends on reaching a certain altitude, but they did not remember the actual height."	Sarter, N.B., & Woods, D.D. (1994)
+5	"2.2 Conclusions (a) Findings ... 7. The autopilot was utilized in basic CWS. 8. The flightcrew was unaware of the low force gradient input required to effect a change in aircraft attitude while in CWS. ..."	NTSB (1972)

DATA SUMMARY

Besides looking at each issue individually, it is valuable to look across all of the issues to identify those that may need more attention or may not be considered in need of attention at this time. We have summarized the information using several methods; two will be presented here. The first is a representation of the top 10 issues with overall positive evidence as measured by the sum of the values of the strength ratings (positive and negative) for each issue. These issues are presented in Table 2. It can be argued that for these issues we now need to focus on solutions, not more research to confirm that they are problems. We have also done this summary based only on the difference between the number of positive evidence records and the number of negative evidence records. The 10 issues remain the same, although the rank order changes somewhat.

Table 2 - Top 10 issues with overall positive evidence measured and ranked by the sum of the strength ratings (positive and negative).

Issue ID	Abbreviated Issue Statement	# pos evid records	# neg evid records	sum of pos evid strength	sum of neg evid strength	sum pos + sum neg	Rank
105	understanding of automation may be inadequate	37	14	94	-31	63	1
83	behavior of automation may not be apparent	18	4	40	-5	35	2
131	pilots may be overconfident in automation	16	4	38	-5	33	3
92	displays (visual and aural) may be poorly designed	32	7	48	-16	32	4
133	training may be inadequate	25	12	48	-17	31	5
106	pilots may over-rely on automation	10	1	28	-1	27	6
40	automation may be too complex	15	3	26	-5	21	7
108	automation behavior may be unexpected and unexplained	16	5	29	-8	21	8
99	insufficient information may be displayed	16	3	26	-6	20	9
65	manual skills may be lost	14	12	37	-17	20	10

It can be seen in Table 2 that Issue105 (also presented in Table 1) is far beyond the other issues on this measure. Besides Issue105, it is interesting to note that the other three issues in the database related to the understanding of automation are also in the top 10: Issue40, Issue108, and Issue133. This suggests that it is clear that problems exist with pilot understanding of automation. Resources should now be committed to identifying and evaluating solutions to these related problems in design, operations, and training. Another area that is represented by two issues in the top 10 list is pilot over-reliance on automation represented by Issue106 and Issue131. Once again, this suggests that problems have been clearly supported in this area and now resources should be committed to developing solutions, although this may be more difficult than those related to the understanding of the automation.

Table 3 presents the other end of the spectrum: those issues that have overall negative evidence based on the sum of the strength ratings. The table represents all the issues with a sum less than zero. The overall weight of available evidence suggests that resources would be better used elsewhere than in the development of solutions to problems suggested by these issues. Further summary of all the issues can be found in Funk, et al. (in press). We also plan to add these to the website.

CONCLUSION

We believe that the work we have done will provide valuable information to those who would like to conduct research on the most pertinent issues related to flight deck automation. Our searchable database can also be used to identify work that has already been accomplished that may lead to possible solutions to these problems.

Table 3 - Issues with overall negative evidence measured and ranked by the sum of the strength ratings (positive and negative).

Issue ID	Abbreviated Issue Statement	# pos evid records	# neg evid records	sum of pos evid strength	sum of neg evid strength	sum pos + sum neg
166	company automation policies and procedures may be inappropriate or inadequate	6	4	8	-9	-1
123	inadvertent autopilot disengagement may be too easy	2	1	2	-3	-1
115	testing may be inadequate	1	1	1	-2	-1
84	crew coordination problems may occur	10	6	11	-14	-3
156	fatigue may be induced	3	4	4	-10	-6
46	pilots may lack confidence in automation	16	12	21	-30	-9
139	inter-pilot communication may be reduced	5	5	7	-16	-9
79	automation may adversely affect pilot workload	19	25	32	-43	-11
13	job satisfaction may be reduced	4	6	4	-18	-14

REFERENCES

Funk, K., Lyall, B., & Riley, V. (1995). Perceived Human Factors Problems of Flightdeck Automation (Phase 1 Final Report for Federal Aviation Administration Grant 93-G-039). Corvallis, OR: Dept. of Industrial and Manufacturing Engineering, Oregon State University. Internet address: http://www.engr.orst.edu/~funkk/Auto/autoprob.html

Funk, K., Lyall, B., Wilson, J., Vint, R., Niemczyk, M., Suretogeh, C., Owen, G. (in press). Flight Deck Automation Issues. International Journal of Aviation Psychology.

NTSB Aircraft Accident Report: Eastern Airlines, Incorporated, L-1011, N31OEA, Miami, FL, December 29, 1972. NTSB-AAR-73-14

Sarter, N.B., & Woods, D.D. (1992) Pilot interaction with cockpit automation: Operational experiences with the Flight Management System. *International Journal of Aviation Psychology 2*(4), 303-321

Sarter, N.B., & Woods, D.D. (1994) Pilot interaction with cockpit automation II: an experimental study of pilot's model and awareness of the Flight Management System. . *International Journal of Aviation Psychology 4*(1), 1-28.

Wiener, E.L. (1989) Human Factors of Advanced Technology ("Glass Cockpit") Transport Aircraft (NASA CR 177528). Moffet Field, CA: NASA Ames Research Center.